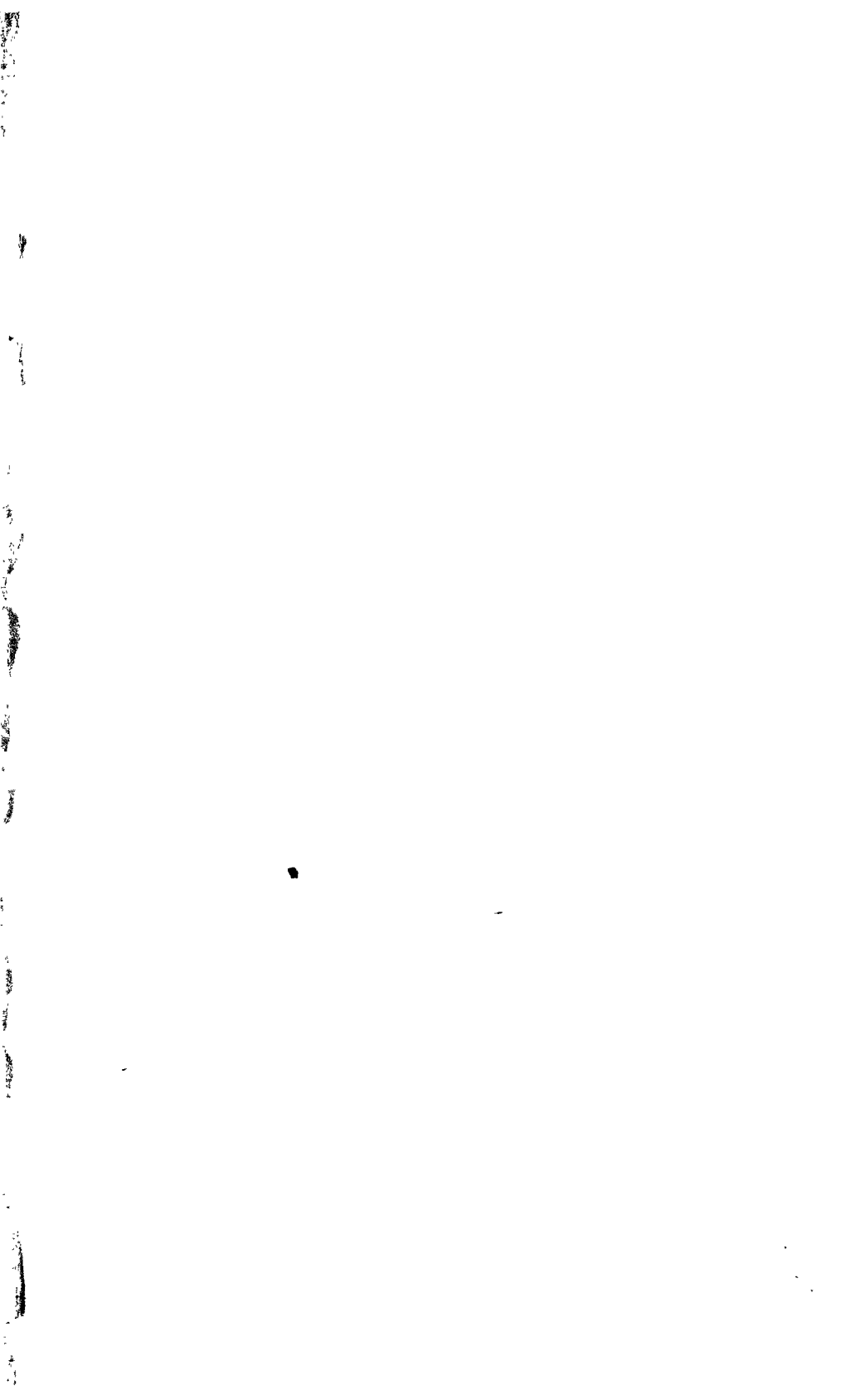


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Annual Report of the Board of Regents

of the
SMITHSONIAN
INSTITUTION
11349



PUBLICATION 4392

*Showing the Operations, Expenditures, and Condition of the
Institution for the Year Ended June 30*

1959



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LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, December 31, 1959.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, on behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ended June 30, 1959. I have the honor to be,

Respectfully,

LEONARD CARMICHAEL, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1959

Presiding Officer ex officio.—DWIGHT D. EISENHOWER, President of the United States.

Chancellor.—EARL WARREN, Chief Justice of the United States.

Members of the Institution:

DWIGHT D. EISENHOWER, President of the United States.

RICHARD M. NIXON, Vice President of the United States.

EARL WARREN, Chief Justice of the United States.

CHRISTIAN A. HERTER, Secretary of State.

ROBERT B. ANDERSON, Secretary of the Treasury.

NEIL H. McELROY, Secretary of Defense.

WILLIAM P. ROGERS, Attorney General.

ARTHUR E. SUMMERFIELD, Postmaster General.

FRED A. SEATON, Secretary of the Interior.

EZRA TAFT BENSON, Secretary of Agriculture.

LEWIS L. STRAUSS, Secretary of Commerce.

JAMES P. MITCHELL, Secretary of Labor.

ARTHUR S. FLEMMING, Secretary of Health, Education, and Welfare.

Regents of the Institution:

EARL WARREN, Chief Justice of the United States, Chancellor.

RICHARD M. NIXON, Vice President of the United States.

CLINTON P. ANDERSON, Member of the Senate.

J. WILLIAM FULBRIGHT, Member of the Senate.

LEVERETT SALTONSTALL, Member of the Senate.

FRANK T. BOW, Member of the House of Representatives.

OVERTON BROOKS, Member of the House of Representatives.

CLARENCE CANNON, Member of the House of Representatives.

JOHN NICHOLAS BROWN, citizen of Rhode Island.

ARTHUR H. COMPTON, citizen of Missouri.

ROBERT V. FLEMING, citizen of Washington, D.C.

CRAWFORD H. GREENEWALT, citizen of Delaware.

CARYL P. HASKINS, citizen of Washington, D.C.

GEROME C. HUNSAKER, citizen of Massachusetts.

Executive Committee.—ROBERT V. FLEMING, chairman, CLARENCE CANNON, CARYL P. HASKINS.

Secretary.—LEONARD CARMICHAEL.

Assistant Secretaries.—J. L. KEDDY, A. REMINGTON KELLOGG.

Assistant to the Secretary.—JAMES C. BRADLEY.

Administrative assistant to the Secretary.—MRS. LOUISE M. PEARSON.

Treasurer.—T. F. CLARK.

Chief, editorial and publications division.—PAUL H. OEHSE.

Librarian.—RUTH E. BLANCHARD.

Curator, Smithsonian Museum Service.—G. CARROLL LINDSAY, acting.

Buildings Manager.—ANDREW F. MICHAELS, JR., acting.

Chief, personnel division.—MRS. ANN S. CAMPBELL, *acting*.

Chief, supply division.—A. W. WILDING.

Chief, photographic service division.—O. H. GREWSON.

UNITED STATES NATIONAL MUSEUM

Director.—A. Remington Kellogg.

Registrar.—Helena M. Weiss.

MUSEUM OF NATURAL HISTORY

Director.—A. C. Smith.

DEPARTMENT OF ANTHROPOLOGY: F. M. Setzler, head curator; A. J. Andrews, exhibits specialist.

Division of Archeology: W. R. Wedel, curator; Clifford Evans, Jr., Ralph S. Solecki, associate curators.

Division of Ethnology: S. H. Riesenbreg, curator; G. D. Gibson, E. I. Knez, associate curators; R. A. Elder, Jr., assistant curator.

Division of Physical Anthropology: T. D. Stewart, curator; M. T. Newman, associate curator.

DEPARTMENT OF ZOOLOGY: Herbert Friedmann, head curator.

Division of Mammals: D. H. Johnson, curator; C. O. Handley, Jr., H. W. Setzer, associate curators.

Division of Birds: Herbert Friedmann, acting curator; H. G. Deignan, associate curator.

Division of Reptiles and Amphibians: Doris M. Cochran, curator.

Division of Fishes: L. P. Schultz, curator; E. A. Lachner, W. R. Taylor, associate curators.

Division of Insects: J. F. G. Clarke, curator; O. L. Cartwright, R. E. Crabill, Jr., W. D. Field, associate curators; Sophy Parfin, assistant curator.

Division of Marine Invertebrates: F. A. Chace, Jr., curator; F. M. Bayer, T. E. Bowman, C. E. Cutress, Jr., associate curators.

Division of Mollusks: H. A. Rehder, curator; J. P. E. Morrison, associate curator.

DEPARTMENT OF BOTANY (NATIONAL HERBARIUM): J. R. Swallen, head curator.

Division of Phanerogams: L. B. Smith, curator; R. S. Cowan, E. C. Leonard, Velva E. Rudd, E. H. Walker, associate curators.

Division of Ferns: C. V. Morton, curator.

Division of Grasses: J. R. Swallen, acting curator.

Division of Cryptogams: M. E. Hale, Jr., acting curator; P. S. Conger, associate curator; R. R. Ireland, Jr., assistant curator.

DEPARTMENT OF GEOLOGY: G. A. Cooper, head curator.

Division of Mineralogy and Petrology: G. S. Switzer, curator; R. S. Clarke, Jr., P. E. Desautels, E. P. Henderson, associate curators.

Division of Invertebrate Paleontology and Paleobotany: G. A. Cooper, acting curator; R. S. Boardman, P. M. Kier, associate curators.

Division of Vertebrate Paleontology: C. L. Gazin, curator; D. H. Dunkle, Nicholas Hotton, 3d, P. P. Vaughn, associate curators; F. L. Pearce, exhibits specialist.

MUSEUM OF HISTORY AND TECHNOLOGY

Director.—F. A. Taylor.

Assistant Director.—J. C. Ewers.

Chief exhibits specialist.—J. E. Anglim.

Chief zoological exhibits specialist.—W. L. Brown.

Assistant chief exhibits specialists.—B. S. Eory, R. O. Hower, B. W. Lawless, Jr.

DEPARTMENT OF SCIENCE AND TECHNOLOGY: R. P. Multhauf, head curator.

Division of Physical Sciences: R. P. Multhauf, acting curator.

Division of Mechanical and Civil Engineering: E. S. Ferguson, curator; E. A. Battison, associate curator; R. M. Vogel, assistant curator.

Division of Transportation: H. I. Chapelle, curator; K. M. Perry, associate curator; J. H. White, assistant curator.

Division of Electricity: W. J. King, Jr., acting curator.

Division of Medical Sciences: G. B. Griffenhagen, curator; J. B. Blake, associate curator.

DEPARTMENT OF ARTS AND MANUFACTURES: P. W. Bishop, head curator.

Division of Agriculture and Wood Products: W. N. Watkins, curator; E. C. Kendall, associate curator.

Division of Textiles: Grace L. Rogers, acting curator.

Division of Ceramics and Glass: P. V. Gardner, acting curator.

Division of Graphic Arts: Jacob Kainen, curator; A. J. Wedderburn, Jr., associate curator; F. O. Griffith, 3d, assistant curator.

Division of Industrial Cooperation: P. W. Bishop, acting curator.

DEPARTMENT OF CIVIL HISTORY: A. N. B. Garvan, head curator; P. C. Welsh, associate curator; A. P. Krimgold, Jr., junior curator.

Division of Political History: W. E. Washburn, curator; Mrs. Margaret B. Klapthor, associate curator; C. G. Dorman, Mrs. Anne W. Murray, assistant curators.

Division of Cultural History: C. M. Watkins, acting curator; J. D. Shortridge, associate curator; Rodris C. Roth, assistant curator.

Division of Philately and Postal History: G. T. Turner, acting curator; F. J. McCall, associate curator.

Division of Numismatics: Vladimir Clain-Stefanelli, acting curator; Mrs. Elvira Clain-Stefanelli, assistant curator.

DEPARTMENT OF ARMED FORCES HISTORY: M. L. Peterson, head curator.

Division of Military History: E. M. Howell, acting curator; C. R. Goins, Jr., assistant curator.

Division of Naval History: M. L. Peterson, acting curator; P. K. Lundeberg, associate curator.

BUREAU OF AMERICAN ETHNOLOGY

Director.—F. H. H. Roberts, Jr.

Anthropologist.—H. B. Collins, Jr.

Ethnologists.—W. C. Sturtevant, W. L. Chafe.

RIVER BASIN SURVEYS.—F. H. H. Roberts, Jr., *Director*; R. L. Stephenson, *Chief, Missouri Basin Project*.

ASTROPHYSICAL OBSERVATORY

Director.—F. L. Whipple.

Associate Directors.—J. A. Hynek, T. E. Sterne.

Astrophysicists.—R. J. Davis, E. L. Fireman, L. G. Jacchia, Max Krook, F. B. Riggs, Jr., C. A. Whitney.

Mathematician.—R. E. Briggs.

TABLE MOUNTAIN, CALIF., FIELD STATION.—A. G. Froiland, *physicist*.

VIII ANNUAL REPORT SMITHSONIAN INSTITUTION, 1959

DIVISION OF RADIATION AND ORGANISMS:

Chief.—W. H. Klein.

Plant physiologists.—V. B. Elstad, Leonard Price.

Electronic engineer.—J. H. Harrison.

Instrument maker.—D. G. Talbert.

NATIONAL COLLECTION OF FINE ARTS

Director.—T. M. Beggs.

Associate curator.—Rowland Lym.

SMITHSONIAN TRAVELING EXHIBITION SERVICE.—Mrs. Annemarie H. Pope, *Chief*.

FREER GALLERY OF ART

Director.—A. G. Wenley.

Assistant Director.—J. A. Pope.

Associate in Near Eastern art.—Richard Ettinghausen.

Associate in technical research.—R. J. Gettens.

Associate curators.—J. F. Cahill, H. P. Stern.

NATIONAL AIR MUSEUM

Advisory Board:

Leonard Carmichael, *Chairman*.

Maj. Gen. Reuben C. Hood, Jr., U.S. Air Force.

Rear Adm. R. E. Dixon, U.S. Navy.

Lt. Gen. James H. Doolittle.

Grover Loening.

Director.—P. S. Hopkins.

Head curator and historian.—P. E. Garber.

Associate curators.—L. S. Casey, W. M. Male, K. E. Newland.

Junior curator.—R. B. Meyer.

NATIONAL ZOOLOGICAL PARK

Director.—T. H. Reed.

Associate Director.—J. L. Grimmer.

Veterinarian.—James F. Wright.

CANAL ZONE BIOLOGICAL AREA

Resident Naturalist.—M. H. Moynihan.

INTERNATIONAL EXCHANGE SERVICE

Chief.—J. A. Collins.

NATIONAL GALLERY OF ART

Trustees:

EARL WARREN, Chief Justice of the United States, *Chairman*.

CHRISTIAN A. HERTER, Secretary of State.

ROBERT B. ANDERSON, Secretary of the Treasury.

LEONARD CARMICHAEL, Secretary of the Smithsonian Institution.

F. LAMMOT BELIN.

DUNCAN PHILLIPS.

CHESTER DALE.

PAUL MELLON.

RUSH H. KRESS.

President.—CHESTER DALE.
Vice President.—F. LAMMOT BELIN.
Secretary-Treasurer.—HUNTINGTON CAIRNS.
Director.—JOHN WALKER.
Administrator.—ERNEST R. FEIDLER.
General Counsel.—HUNTINGTON CAIRNS.
Chief Curator.—PERRY B. COTT.

Honorary Research Associates, Collaborators, and Fellows

OFFICE OF THE SECRETARY

John E. Graf

UNITED STATES NATIONAL MUSEUM

MUSEUM OF NATURAL HISTORY

Anthropology

Mrs. Arthur M. Greenwood.
 N. M. Judd, Archeology.
 H. W. Krieger, Ethnology.
 Betty J. Meggers, Archeology.

H. Morgan Smith, Archeology.
 W. W. Taylor, Jr., Archeology.
 W. J. Tobin, Physical Anthropology.

Zoology

Paul Bartsch, Mollusks.
 J. Bruce Bredin.
 M. A. Carriker, Insects.
 C. J. Drake, Insects.
 Isaac Ginsberg, Fishes.
 D. C. Graham, Biology.
 Horton H. Hobbs, Jr., Marine
 Invertebrates.
 A. B. Howell, Mammals.
 Laurence Irving, Birds.
 W. L. Jellison, Insects.

W. M. Mann, Hymenoptera.
 Allen McIntosh, Mollusks.
 J. P. Moore, Marine Invertebrates.
 C. F. W. Muesebeck, Insects.
 W. L. Schmitt.
 Benjamin Schwartz, Helminthology.
 R. E. Snodgrass, Insects.
 T. E. Snyder, Insects.
 Alexander Wetmore, Birds.
 Mrs. Mildred S. Wilson, Copepod
 Crustacea.

Botany

Mrs. Agnes Chase, Grasses.
 E. P. Killip, Phanerogams.

F. A. McClure, Grasses.
 J. A. Stevenson, Fungl.

Geology

R. S. Bassler, Paleontology.
 R. W. Brown, Paleobotany.
 Preston Cloud, Invertebrate
 Paleontology.

C. Wythe Cooke, Invertebrate
 Paleontology.
 J. B. Knight, Invertebrate Paleon-
 tology.
 W. T. Schaller, Mineralogy.

MUSEUM OF HISTORY AND TECHNOLOGY

History

Elmer C. Herber.

F. W. MacKay, Numismatics.

BUREAU OF AMERICAN ETHNOLOGY

J. P. Harrington.

Sister M. Inez Hilger.

M. W. Stirling.

A. J. Waring, Jr.

ASTROPHYSICAL OBSERVATORY

C. G. Abbot.

FREER GALLERY OF ART

Oleg Grabar.

Grace Dunham Guest.

Max Loehr.

Katherine N. Rhoades.

NATIONAL AIR MUSEUM

Frederick C. Crawford.

John J. Ide.

NATIONAL ZOOLOGICAL PARK

W. M. Mann.

E. P. Walker.

CANAL ZONE BIOLOGICAL AREA

C. C. Soper.

Report of the Secretary of the Smithsonian Institution

LEONARD CARMICHAEL

For the Year Ended June 30, 1959

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit a report showing the activities and condition of the Smithsonian Institution and its branches for the fiscal year ended June 30, 1959.

GENERAL STATEMENT

The activities of the 113th year of the Smithsonian Institution are presented in this report. In many ways this has been an outstanding year at the Smithsonian. Once again the services rendered by the Institution demonstrate the wisdom of our distinguished founder and man of science, James Smithson, in establishing in Washington an institution for the "increase and diffusion of knowledge among men." The increase in knowledge is embodied in research, and this year the investigations of the Smithsonian staff have been very fruitful, as the details given herein will indicate. The diffusion of knowledge has involved the answering of some 260,000 specific inquiries related to the fields of expertness found in the Smithsonian's various divisions, laboratories, and libraries. The diffusion of knowledge has also been actively carried on by the publication of scholarly and semipopular works, which are also described elsewhere in this report. Possibly, however, the main means by which the Smithsonian Institution diffuses knowledge is through its museum exhibits and the educational and inspirational opportunity that these displays give to our millions of visitors each year.

As pointed out in recent annual reports, real progress has been made in the past few years in transforming the old, outmoded museum displays of the Smithsonian into modern, effective, teaching exhibits. The visitors who now come to the Smithsonian Institution are deeply grateful that Congress has made it possible to bring about this gradual transformation of Smithsonian exhibition halls from what in too many respects was until recently an old-fashioned place for "visual storage."

In 1954, for the first time in the long history of the Smithsonian Institution, a fully outlined program was adopted for the progressive improvement of all its exhibition halls and for the modern presentation of tens of thousands of appropriate objects from the great national collections that are in its charge. This modernization is now complete in 17 major galleries. To put this in another way, a total of about 80,000 square feet of exhibition space has now been transformed, and 673 separate exhibit units have been fully reorganized and modernized for the benefit and education of the public.

Before this modernization program began, many of the Smithsonian Institution exhibits had not been changed for as long as 75 years. Amazing as it may seem, the great and often unique treasures of the Institution, which today include over 52 million cataloged objects, were still being displayed in a manner that had long before become outmoded in almost every other national museum in the world. When the present transformation began, for example, gas fixtures were still in place, although not in use, in some of our exhibition halls. In a few large sections of Smithsonian buildings there was as recently as 5 years ago no provision for artificial light of any kind either in display cases or in public spaces. This meant that on many winter afternoons some of the great treasures of the Smithsonian were almost invisible to visitors.

It may be pointed out that all around the globe, especially since the Second World War, there has been a new recognition of the role of the museum as a public information center. More and more museums are seen as places needed to inspire each new generation with the kind of patriotism that is based on a valid understanding of the factors that have led to national growth. The history of the development of science, for example, as displayed in a modern museum has a significant function in interesting and inspiring a real interest in science on the part of school boys and girls.

This new museum philosophy has been wholeheartedly accepted and adopted at the Smithsonian. The experts in each of its great subject-matter fields have given much thought to developing the best ways to present their exhibits so as to meet this modern and challenging view of what a museum should be. The present objective of renovation at the Smithsonian, therefore, is not only to show many interesting objects in a clear way but also to explain how and why the particular items selected for display are intellectually significant. An old shoe with a wooden sole is unimportant alone, but when shown as part of the field equipment of a soldier of the Confederate States of America it explains much about the problems of equipment during the Civil War.

At the present time as a visitor studies the presentation of objects in any of the modernized exhibition halls of the Institution, he can

see clearly illustrated such great ideas as man's use of natural resources and man's gradual triumph in the long development of specific arts and sciences.

The newly modernized exhibits of the Smithsonian cover diverse fields. For example, the displays of the anthropology, ethnology, and archeology of the New World before Columbus have been admirably rearranged. The birds of the world are presented as important and beautiful in themselves and as significant elements in the economy of nature and in zoological science in general. A large section is devoted to the great mammals of America, showing in artistic and accurately composed habitat groups the way in which such animals as the bison, the wolves, and the elk lived. The geological sciences are presented in a new exhibition hall, which has been called the most notable display of its kind in the world. Here minerals, gems, and the new Vetlesen jade collection are most clearly displayed. But the minerals actually shown are not more than 3 percent of the total Smithsonian study collections in this field.

For more than a century the Smithsonian Institution has been assembling unequaled collections of important items dealing with the history of the United States. Some of the most significant of these have never been displayed for the benefit of the public. Now thousands of these objects are presented in an appropriate and instructive manner. Typical of the display of historic materials is the hall in which the dresses of the First Ladies of the White House are shown, each in an authentic setting. In the period room in which Martha Washington's dress is shown, for example, there are exhibited only objects that belonged to and were used by George Washington himself. The halls of American military history have been transformed, and the displays of many of the arts and manufacturing processes have also been entirely made over. Among other new displays is a hall for the presentation of machines and products used in the graphic arts and one for textiles and textile machinery. In the latter hall a great Jacquard loom has been installed in operating condition, with its amazing punch-card mechanism clearly explained to the visitor. Another new exhibit is a complete 17th-century American house brought piece by piece from Massachusetts and carefully and authentically reerected and furnished with objects of everyday use of just the sort employed by early New England Colonial families.

One indirect result of the still far from complete modernization program of the Smithsonian has been an increase in the use of the study collections of the Institution by research workers. Students in schools and colleges now also come in larger numbers to the new exhibition halls of the Institution. Some come alone or with parents and some under the supervision of teachers. In the new halls

they learn as they cannot elsewhere important lessons about the natural resources of America, the natural history of the world, and special aspects of the history of their own United States. Many leave better informed and are more truly patriotic Americans than when they came. As noted elsewhere in this report, volunteer, unpaid but well-trained docents from the Junior League of Washington instruct thousands of schoolchildren each year as they carefully lead them through specially selected halls on educational tours.

The modernization program has had a great effect on attendance at the Smithsonian. The number of visitors to the Smithsonian, not including the National Gallery of Art or the National Zoological Park, in 1954, when the modernization of exhibits program began, was 3,658,000. The attendance of the year covered by this report, 1959, was, as is elsewhere noted, 6,351,000. This phenomenal increase in number of visitors is certainly due in considerable measure to the new interest generated by the modernized exhibits.

The staff of the Smithsonian Institution has planned and is continuing active work on the modernization of an additional 28 exhibition halls in our existing buildings. It is also engaged in planning and preparing exhibits for 47 large halls in the Smithsonian's new Museum of History and Technology Building, which is being erected on Constitution Avenue between 12th and 14th Streets.

This total exhibit-development program in the Smithsonian, therefore, will, when it is completed, have included well over a hundred large galleries or major halls and literally thousands of specific exhibition units. These units will in sum total display for the public more than a million objects from our unrivaled national collections in new, clear, and intelligible settings.

The Smithsonian Institution has long been called the Nation's Treasure House. When the modernization program described in the preceding paragraphs is complete and when the new Museum of History and Technology Building is opened, certainly this great national treasury will at long last be presented in a way that is worthy of modern America.

When James Smithson specified that he wished his institution to be concerned not only with research but also with the diffusion of knowledge, he set a pattern that has inspired the devoted and effective work of the staff of his institution that has made this modernization program so successful.

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, in accordance with the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smith-

sonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and, therefore, constituted an "establishment," whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

The current year brought the retirement of two members of the Board of Regents: Senator H. Alexander Smith and Representative John M. Vorys. At the time of the annual meeting the Speaker of the House of Representatives appointed Representative Frank T. Bow of Ohio to succeed Representative John M. Vorys. On February 5, 1959, the Vice President appointed Senator J. William Fulbright of Arkansas to succeed Senator H. Alexander Smith.

The roll of Regents at the close of the fiscal year was as follows: Chief Justice of the United States Earl Warren, Chancellor; Vice President Richard M. Nixon; members from the Senate: Clinton P. Anderson, J. William Fulbright, Leverett Saltonstall; members from the House of Representatives: Frank T. Bow, Overton Brooks, Clarence Cannon; citizen members: John Nicholas Brown, Arthur H. Compton, Robert V. Fleming, Crawford H. Greenewalt, Caryl P. Haskins, and Jerome C. Hunsaker.

On the evening of January 15, 1959, preceding the annual meeting, an informal dinner was given in the main hall of the Smithsonian Building amid various exhibits showing the present-day phases of the work of the bureaus and departments. Dr. Richard Ettinghausen spoke on "Objects Dealing with Christian Themes in the Freer Gallery Collections"; Dr. Charles Lewis Gazin on "Eocene Mammals of the Bridger Formation in Southwestern Wyoming"; Dr. Vladimir Clain-Stefanelli on "Comparative Die Studies: A Method of Numismatic Investigation and Its Historical Significance"; and Edgar M. Howell on "Private Hermann Steiffel—Sometime Artist of the West."

The annual meeting was held on January 16, 1959. The Secretary presented his published annual report on the activities of the Institution together with the 1958 Annual Report of the United States National Museum. The Chairman of the Executive and Permanent Committees of the Board, Dr. Robert V. Fleming, gave the financial report for the fiscal year ended June 30, 1958.

FINANCES

A statement on finances, dealing particularly with Smithsonian private funds, will be found in the report of the executive committee

of the Board of Regents, page 234. Funds appropriated to the Institution for its regular operations for the fiscal year ended June 30, 1959, totaled \$7,587,800. Besides this direct appropriation, the Institution received funds by transfer from other Government agencies as follows:

From the District of Columbia for the National Zoological Park..... \$953,800
 From the National Park Service, Department of the Interior, for the
 River Basin Surveys..... 162,000

VISITORS

Visitors to the Institution's exhibition halls continue to increase. Visitors to the Smithsonian group of buildings on the Mall reached a total of 6,351,352, an all-time high and nearly a million more than the previous year. April 1959 was the month of largest attendance, with 978,230; May 1959 second, with 867,817; August 1958 third, with 769,086. Largest attendance for a single day was 92,945 on April 12, 1959. Table 1 gives a summary of the attendance records for the five buildings; table 2, groups of schoolchildren. These figures, when added to the 951,608 visitors recorded at the National Gallery of Art and the 4,055,673 estimated at the National Zoological Park, bring the year's total number of visitors at the Institution to 11,358,633.

TABLE 1.—*Visitors to certain Smithsonian buildings during the year ended June 30, 1959*

Year and month	Smithsonian Building	Arts and Industries Building	Natural History Building	Aircraft Building	Freer Building	Total
<i>1958</i>						
July.....	105,654	310,882	150,153	97,050	12,872	676,611
August.....	141,457	312,426	175,188	125,124	14,891	769,086
September....	49,885	122,427	68,848	40,766	8,682	290,608
October.....	45,002	115,621	96,748	34,129	7,502	299,002
November....	55,269	127,064	146,618	38,483	7,488	374,922
December.....	27,724	57,956	73,220	20,221	4,018	183,139
<i>1959</i>						
January.....	32,672	72,515	86,980	25,461	6,248	223,876
February.....	46,899	103,074	109,682	36,037	6,218	301,910
March.....	110,821	229,864	209,894	69,695	10,825	631,099
April.....	170,520	392,353	303,991	96,800	14,566	978,230
May.....	139,186	301,701	319,018	95,398	12,514	867,817
June.....	126,039	286,978	217,407	111,119	13,509	755,052
Total.....	1,051,128	2,432,861	1,957,747	790,283	119,333	6,351,352

TABLE 2.—Groups of schoolchildren visiting the Smithsonian Institution during the year ended June 30, 1959

Year and month	Number of children	Number of groups
<i>1958</i>		
July.....	7, 670	301
August.....	8, 648	405
September.....	4, 433	145
October.....	19, 534	644
November.....	21, 083	612
December.....	9, 801	295
<i>1959</i>		
January.....	9, 769	346
February.....	18, 339	581
March.....	54, 235	1, 426
April.....	110, 950	2, 431
May.....	148, 789	3, 338
June.....	44, 424	1, 354
Total.....	457, 675	11, 878

SUMMARY OF THE YEAR'S ACTIVITIES

National Museum.—The national collections were augmented during the year by a total of 1,144,445 specimens, bringing the total catalog entries in all departments to more than 52 million. Some of the outstanding items received included: In anthropology, a 12th-century stone Buddha from Cambodia, 4 collections of Micronesian ethnological material, and a cast of the Gánovce (Slovakia) Neanderthal skull; in botany, the entire herbarium of Goucher College, consisting of about 6,100 specimens; in geology, the legendary Hope diamond, a superb collection of Chinese jade carvings, the largest dinosaur bone known from this country, and more than 7,300 specimens of Carboniferous plants; in zoology, large lots of mammals and birds from Panama, 2 large collections of fishes from the eastern United States; the Monrós collection of more than 54,000 chrysomelid beetles, and many mollusks and marine invertebrates collected by the Bredin-Smithsonian Caribbean Expedition; in civil history, an entire room from the Gothic Revival Harral-Wheeler house in Bridgeport, Conn., an entire 18th-century loghouse from Wilmington, Del., additions to the White House china collection, and important lots of philatelic and numismatic material, including the Dwight D. Eisenhower collection of coins, medals, and memorabilia; in Armed Forces history, early U.S. military and naval insignia from the W. Stokes

Kirk collection and 117 original drawings of U.S. sailing ships; in arts and manufactures, several important gifts of ceramics and glass, a group of fine prints, and an 18th-century French hand-and-foot treadle loom for the new textile hall; and in science and technology, a collection of early handmade locks, bolts, and decorative hardware, an acquisition of dental instruments, furniture, and equipment relating to the history of dentistry, and a group of scientific instruments used by Ira Remsen at Johns Hopkins University.

Members of the staff conducted fieldwork in Central America, South America, the Caribbean, Europe, and many parts of the United States.

Under the exhibits-modernization program, three new halls were opened to the public during the year—the Graphic Arts Hall, the Hall of Gems and Minerals, and the Textile Hall. An event of the year of particular public interest was the unveiling of the Fénykövi elephant in the rotunda of the Natural History Building. Fitting ceremonies were also held in connection with the opening of the room displaying the Maude Monell Vetlesen collection of Chinese jade carvings.

Bureau of American Ethnology.—The members of the Bureau staff continued their research in archeology and ethnology: Director Roberts particularly on matters pertaining to the River Basin Surveys, Dr. Collins his Arctic and Eskimo studies, Dr. Sturtevant his Seminole and Seneca researches, Mr. Miller his archeological work at Russell Cave in Alabama.

Astrophysical Observatory.—The year's researches of the Smithsonian Astrophysical Observatory have embraced solar astrophysics, upper atmosphere studies, meteoritical studies, and satellite science. The satellite-tracking program was continued, with notable results. The division of radiation and organisms continued its researches on the photomorphogenic mechanism in plants as controlled by radiant energy.

National Collection of Fine Arts.—The Smithsonian Art Commission accepted for the Gallery 19 bronzes, 1 bronze plaque, 4 medallions, 3 oils, and 4 watercolors. The Gallery held 17 special exhibitions during the year; and the Smithsonian Traveling Exhibition Service circulated 100 exhibitions (29 new and 71 held from previous years) to 240 museums.

Freer Gallery of Art.—Purchases for the Freer Gallery Collections included outstanding examples of Syrian glass; Indian lacquerwork; Indian and Persian metalwork; Indian, Chinese, and Japanese painting; and Chinese and Japanese pottery. The Gallery continued its program of illustrated lectures by distinguished scholars in the auditorium, the 1958-59 season numbering six.

National Air Museum.—Site for the new building for the National Air Museum was approved during the year, and preliminary studies

and estimates of planning costs are in progress. During the year 341 specimens in 56 separate accessions were added to the aeronautical collections, including an early example of a German one-man helicopter, a DM-1 delta-winged glider of World War II, the Jupiter "C" missile and the recovered nose cone of the Jupiter "C," the "Data-Sphere" (a recovered instrumented capsule from a long-range ballistic missile), and a large quantity of documents and memorabilia pertaining to the pioneer rocketry research by Dr. Robert H. Goddard.

National Zoological Park.—The Zoo accessioned 1,286 animals during the year. The net count at the close of the year was 2,384. Noteworthy among the additions were a herd of 14 reindeer from Kotzebue, a trio of Rocky Mountain goats and 5 pronghorns, 6 albatrosses, the first Dall sheep ever to be exhibited in an American zoo, and a pair of Pallas's cats. A female wisent was born in captivity.

Canal Zone Biological Area.—About 400 persons visited the island during the year, including 54 scientists, students, and observers using the station's facilities for special researches, particularly in plant and insect studies, wildlife observation, nature writing, and photography.

International Exchange Service.—As the official U.S. agency for the exchange of governmental, scientific, and literary publications between this country and other nations, the International Exchange Service handled during the year 1,129,476 packages of such publications, weighing 767,389 pounds.

National Gallery of Art.—The Gallery received 370 accessions during the year, by gift, loan, or deposit. Eight special exhibits were held, and 27 traveling exhibitions of prints from the Rosenwald Collection were circulated elsewhere. Exhibitions from the "Index of American Design" were given 43 bookings in 17 States and the District of Columbia, and 1 in Germany. More than 40,500 persons attended the general tours conducted by Gallery personnel, and more than 11,500 attended tours, lectures, and conferences by special appointment. The Sunday afternoon auditorium lectures drew 14,500 persons. The Sunday evening concerts in the east garden court were continued.

Library.—The library received a total of 52,669 publications during the year, and 159 new exchanges were arranged. At the close of the year the holdings of the library and its branches aggregated 982,596 volumes, including 586,722 in the Smithsonian Deposit at the Library of Congress but excluding unbound periodicals and reprints and separates of serial publications.

Publications.—Eighty-one publications appeared under Smithsonian imprint during the year. (See Report of Publications, p. 224, for full list.) Outstanding among these were: "Studies in Inverte-

brate Morphology," papers by 18 contributors published in honor of Dr. Robert Evans Snodgrass; "Pueblo del Arroyo, Chaco Canyon, New Mexico," by Neil M. Judd; "The Journals of Daniel Noble Johnson (1822-1863), United States Navy," edited by Mendel L. Peterson; "First Book of Grasses," third edition, by Agnes Chase; "Checklist of the Millipeds of North America," by Ralph V. Chamberlin and Richard L. Hoffman; "Ichneumon-flies of America North of Mexico," by Henry and Marjorie Townes; "The Native Brotherhoods: Modern Intertribal Organizations on the Northwest Coast," by Philip Drucker; "The North Alaska Eskimo: A Study in Ecology and Society," by Robert F. Spencer.

Personnel.—Lawrence L. Oliver, buildings manager, retired on May 31, 1959, after 38 years of service with the Institution. Charles C. Sinclair, assistant buildings manager, retired on February 24, 1959; he had been with the Smithsonian since 1935.

Other changes in staff made during the year are noted as appropriate in the reports of the various branches of the Institution that follow.

Report on the United States National Museum

SIR: I have the honor to submit the following report on the condition and operations of the U.S. National Museum for the fiscal year ended June 30, 1959:

COLLECTIONS

Specimens incorporated into the national collections totaled 1,144,445, distributed among the eight departments as follows: Anthropology, 14,497; zoology, 452,163; botany, 50,641; geology, 139,070; Armed Forces history, 934; arts and manufactures, 12,699; civil history, 469,612; science and technology, 4,829. This increase is smaller than last year, when an unusual accretion resulted from the accession of a large number of stamps. This year's total is a more normal figure. Most of the accessions were acquired as gifts from individuals or as transfers from Government departments and agencies. The Annual Report of the Museum, published as a separate document, contains a detailed list of the year's acquisitions, of which the more important are summarized below. Catalog entries in all departments now total 52,022,520.

Anthropology.—Prince Norodom Sihanouk, formerly King of Cambodia and now Prime Minister of that country, presented to the people of the United States through President Dwight D. Eisenhower a fine example of a stone Buddha, seated on a coiled serpent (the King Muchilinda) and protected by a crown of seven heads of the serpent. The Buddha was made in the Cambodian city of Angkor Thom during the reign of King Jayavarmon VII, A.D. 1181–1215.

Four collections, totaling 249 specimens, were received by transfer from the Department of the Interior, through Delmas H. Nucker, High Commissioner, Trust Territory of the Pacific Islands, from the districts of Yap, Truk, Ponape, and the Marshall Islands. These specimens, obtained especially for the division of ethnology, considerably enrich the material from Micronesia, an area until now not well represented in the national collections. Among them are two fishing kites from Ifalik, which are flown from canoes and from which dangle a ball of cobwebs for catching garfish. After a fish strikes the sticky substance it cannot open its mouth. There is a war club from Satawan, some excellent knuckle dusters and weather charm

idols, belt looms with ring-woven fabrics, and a good stick chart used as a native navigational device by the Marshall Islanders.

Several archeological accessions are of especial interest. One is a plaster cast of a colossal stone head of the Olmec culture (ca. 500 B.C.), the original of which was found near San Lorenzo in southern Veracruz, Mexico. The cast was received in 31 pieces, which were assembled, painted, and placed on exhibit in the Highlights of Latin American Archeology Hall. A collection of primitive stone implements from northern Australia, collected by F. D. McCarthy, of the Australian Museum, and Frank M. Setzler during the Smithsonian-National Geographic Society Arnhem Land Expedition in 1948, constitutes an unusual accession. Type samples and all unique specimens collected in British Guiana in 1952-53 by the Smithsonian Institution-Fulbright Research Fellowship Expedition have added much to the Museum's collections from South America.

New accessions in the division of physical anthropology include a plaster cast of the Gánovce Neanderthal skull found in 1926 in a travertine quarry in northern Slovakia. The original is a travertine cast of the endocranial cavity with only a little adherent cranial bone still in place. So far as is known, no other copy of this important specimen has reached the United States. A skull (with parts of the skeleton) exhibiting filed teeth was found in January 1954 by Dr. Preston Holder in a burial pit at the great Cahokia Mound site in East St. Louis, Ill. Although the pit contained the skeletal remains of a number of individuals, only the one skeleton has filed teeth, and the fact that it alone was articulated suggests that filed teeth were a sign of distinction. One of the conclusions reached, in a report published in the November 1958 *Journal of the Washington Academy of Sciences*, is that the custom of tooth filing in the Mississippi Valley probably had its origin in Middle America but became attenuated and modified.

Botany.—Significant gifts to the department of botany were 130 slides of diatoms, presented by Mrs. Eloise Stump, Oak Park, Ill.; 6,133 specimens given by Goucher College, Baltimore, Md., consisting of their entire herbarium, including a large number of cryptogams; 388 plants of Australia from Dr. C. L. Wilson, Hanover, N.H.; and 1,749 mosses contributed by E. C. Leonard from his personal collection.

Among the numerous exchanges were 4,875 specimens of Sumatra and the East Indies from the University of Michigan; 1,152 specimens of Canadian and Arctic plants, received from the Canada Department of Agriculture; 1,403 specimens from Cuba received from the Colegio de la Salle, Havana; 921 specimens, collected in Argentina by T. M. Pedersen, from the Botanical Museum, University of Copenhagen; 1,002 specimens of New Guinea and Australia from the Commonwealth Scientific and Industrial Research Organization, Canberra, Australia;

352 plants, collected by Dr. Bassett Maguire in the "Lost World" region of Venezuela, from the New York Botanical Garden; and 282 plants from the V. L. Komarov Botanical Institute, Academy of Sciences of the USSR, consisting of issues 81-84 of their "Herbarium of the Flora of the USSR" and "Decas I-V Hepaticae and Musci USSR Exsiccati."

Several large collections were received with identifications requested, including 490 specimens, collected in Colombia by Jean Langenheim, from the University of California; 943 plants of Santa Catarina, Brazil, from the *Herbário "Barbosa Rodrigues," Itajaí, Santa Catarina, Brazil*; and 268 miscellaneous South American specimens from the *Muséum National d'Histoire Naturelle, Paris*.

Dr. Mason E. Hale and Robert R. Ireland collected 4,295 lichens and 1,491 mosses on field trips in Virginia in connection with their research projects. Transferred from the Department of the Interior were 1,851 plants of Polynesia collected by Dr. F. R. Fosberg. There were purchased from the Archbold Expeditions 1,902 specimens collected by L. J. Brass on the Fifth Archbold Expedition to New Guinea; from Paul Aellen, Basel, Switzerland, 1,140 specimens collected by Dr. K. Rechinger in Iran and Greece; and from Winifred M. A. Brooke, Liss, England, 830 plants she collected in Sarawak.

Geology.—The legendary Hope diamond, the largest and most notable of all blue diamonds, was presented on November 10, 1958, by Harry Winston, New York gem merchant and connoisseur. The Hope diamond ranks in importance with other famous gems, such as the Kohinoor, Cullinan, and Regent, found only in the Crown Jewels of Europe. Because of its long and dramatic history, the legends built around it, and its rare, deep-blue color, the Hope diamond is probably the best known diamond in the world. Mr. Winston acquired it in 1949 from the estate of the late Mrs. Evalyn Walsh McLean, of Washington, who received it from her husband, Edward B. McLean, in 1911. Its known history prior to the McLean purchase dates from 1830, when David Eliason, a noted gem dealer, sold the stone to Henry Thomas Hope, an Irish squire and banker. The stone was shown at the London Exposition in 1851. In 1867 it was sold at Christie's in London. It was acquired in 1908 by the Sultan Habis Bey, but after the Young Turks Revolt the gem was again placed on the market and purchased by Mr. McLean in 1911.

One of the world's finest collections of Chinese jade carvings was presented by the estate of Mrs. Maude Monell Vetlesen through her son, Edmund C. Monell. The collection comprises 130 pieces, carved in one or the other of the two jade minerals, nephrite or jadeite. Some of the specimens date from the Ming Dynasty (1368-1644), but most are from the Ching Dynasty (1644-1912). Noteworthy gifts in min-

erals received from individuals are: genthelvite, Colorado, from Glenn R. Scott; opal, Nevada, from Mark C. Bandy; jade, Burma, from Martin L. Ehrmann; milky quartz crystals, Colorado, from E. M. Gunnell; gorceixite, French Equatorial Africa, from Mahlon Miller; spangolite, Arizona, from Arch Oboler; and clinchedrite and roebbingite, New Jersey, from John S. Albanese.

Important additions to the Roebling collection by purchase and exchange include a collection of 249 specimens of exceptional rarity and quality; a fine large crystal of phosphophyllite from Bolivia; a crystal of beryl, variety aquamarine, from Brazil; bikitaite from Southern Rhodesia; an unusually large mass of thorite from Colorado; danburite from Mexico; and four tourmaline crystals from Mozambique.

Several items of outstanding exhibition quality were added to the Canfield collection by purchase. Among these are proustite from Chile; spodumene from Brazil; pyrite from Colorado; euclase from Brazil; smoky quartz from Switzerland; and cyrtolite from Colorado.

Gems and jewels acquired for the Isaac Lea collection by purchase from the Chamberlain fund include a 10.8-carat kornerupine from Madagascar; an 18.5-carat golden sphalerite from Utah; a colorless zircon from Ceylon, weighing 48.2 carats; a star garnet sphere weighing 67.3 carats, from Idaho; and a 43.4-carat sinhalite from Ceylon.

Important additions to the meteorite collection include the following: Ladder Creek, Kans., from the Argonne National Laboratory; Vera, Santa Fé, Argentina, from Lorenzo Orestes Giacomelli; Belle Plaine, Kans., from Prof. Walter Scott Huston; Idutwa, Cape Province, South Africa, from Dr. Edgar D. Mountain; Nuevo Laredo, Mexico, from C. C. Patterson; and Sikhote-Alin, Union of Soviet Socialist Republics, from the USSR Academy of Sciences.

In the division of vertebrate paleontology the outstanding accession of the year resulted from fieldwork by Peter P. Vaughn, who obtained excellent materials representing a number of genera of fishes, amphibians, and reptiles from the Clyde and Arroyo formations of Baylor County, Tex. A dinosaur bone, the largest known from this country, 6 feet 10 inches long, a humerus of the Jurassic genus *Brachiosaurus*, was donated by D. E. Jones. Two accessions of fossil fishes received in exchanges furnished exhibition material: one, a specimen of the Triassic coelacanth *Diplurus newarki*, together with its life restoration to scale, was received from Princeton University; the other includes 81 specimens of fossil sharks and ray-finned fishes from two marine Upper Cretaceous formations in Lebanon from the School of Engineering, American University of Beirut, through Dr. Harry M. Smith. Of mammalian materials acquired, the skull of the Miocene whale *Cetotherium megalophysum* is outstanding. It was

collected by Capts. Daniel and Edward Harrison of Ewell, Md., and was presented by the Ewell Junior High School.

Among the important gifts received in the division of invertebrate paleontology and paleobotany are 7,345 specimens of Carboniferous plants collected by Dr. Harvey Bassler, received from the Maryland Department of Geology, Mines, and Water Resources, Johns Hopkins University; 23 type specimens of Miocene mollusks from the Chesapeake Bay area from Dr. John Oleksyshyn, Boston University; 144 slides of Recent Foraminifera and Ostracoda from the Antarctic from Rear Adm. Charles W. Thomas; 63 specimens of Oligomiocene ostracods from the Brasso formation of Trinidad from Dr. W. A. van den Bold; 200 Mesozoic invertebrate fossils from Israel from Dr. J. Wahrman; and 263 foraminiferal concentrates and well cuttings from Italian Somalia from the Sinclair Oil and Gas Co.

Through funds provided by the Walcott bequest 438 invertebrate fossils, including over 400 goniatites from Oklahoma, were acquired by the Museum. A grant from the National Science Foundation permitted Associate Curator Porter M. Kier to collect 1,490 echinoids and other invertebrate fossils in Belgium, France, Holland, and Switzerland.

Among the important exchanges received are 750 specimens of assorted invertebrate fossils from the Mesozoic and Tertiary of Great Britain from Sgt. Philip Cambridge; 61 blocks of Permian limestone from West Texas from Harvard University through Dr. H. B. Whittington; and one specimen of the very rare brachiopod *Enantiosphen* from the Devonian of Germany donated by Dr. Wolfgang Struve, Senckenberg Museum, Frankfurt, Germany.

Zoology.—The largest accession and the largest single collection to be received in the division of mammals in several years includes more than 1,600 specimens from Panama collected by C. O. Handley, Jr., and Bernard Feinstein in cooperation with the Gorgas Memorial Laboratory. More than a hundred mammals, including a specimen of the rare suni antelope, were collected in East Africa and presented by Judge Russell E. Train. Antarctic explorations connected with the International Geophysical Year, under the auspices of the National Academy of Sciences, brought a specimen of the rare Ross seal. Individual specimens of unusual interest are the skin of a snow leopard collected in the Himalayas by Maj. Gen. M. Hayaud Din and presented by the Embassy of Pakistan, and the unique type specimens of a new race of the large spiny rat *Haplomys gymnurus* collected by Dr. A. Wetmore on the tiny island of Escudo de Veraguas, Panama.

An important accession to the bird collection consisted of 572 birdskins amassed in Panama by Dr. A. Wetmore. Another large acces-

sion of 591 skins of birds and other ornithological material from North America was transferred from the Fish and Wildlife Service, Department of the Interior. The Public Health Service, Department of Health, Education, and Welfare, also transferred 75 birdskins from Arctic America. The rarest single specimen received was a lyre-tailed honeyguide, *Malichneutes robustus*, from Cameroons, a gift from the Zoological Society of London. This is the second known example of this bird to come to an American museum.

In reptilian and amphibian material a number of accessions of types and paratypes of recently described species was received, the most notable single lot being a gift of 172 specimens from Haiti, Cuba, and Trinidad, received from Dr. W. G. Lynn.

The division of fishes received two large collections of fresh-water fishes from the eastern United States. One of these, comprising 25,057 specimens, is an exchange from the University of South Carolina through Dr. Harry Freeman; the other, consisting of 25,000 fishes, was donated by the University of Maryland through Dr. G. W. Wharton. The Woods Hole Oceanographic Institution gave 852 fishes from Labrador through Dr. Richard H. Backus. A very fine collection totaling 2,449 fishes from the eastern Pacific was presented by the University of California through Wayne J. Baldwin. This group includes numerous species not otherwise represented in the national collections.

Several outstanding collections were acquired by the division of insects: the Monrós collection of 54,245 chrysomelid beetles transferred by the U.S. Department of Agriculture; 30,507 insects collected in El Salvador by O. L. Cartwright; 26,385 specimens of beetles from Europe, Asia, and the Americas, collected and donated by Paul J. Spangler; the Fish and Wildlife Service transferred 33,063 miscellaneous New World insects through Dr. Daniel L. Leedy; N. L. H. Kraus presented 6,924 insects from Asia, from many localities not previously represented in the national collections. Other important accessions are as follows: From Dr. W. B. Muchmore some 800 New York State centipedes, providing valuable records being incorporated into a statewide survey that is currently in preparation; from Dr. Thomas C. Barr, Jr., a number of cave collections of centipedes, giving information about unexplored fauna; and from Dr. George E. Ball, some 1,000 centipedes, comprising the largest chilopod collection known to date from Alaska and adjacent islands.

The outstanding accession of mollusks was a gift from Dr. R. L. Alsaker of some 280 specimens of marine species of the family Volu-tidae, including many rare and beautiful forms. Other notable accessions include 900 lots, 3,100 specimens, of mollusks from the British Virgin Islands and the Leeward Islands, collected by the Bredin-

Smithsonian Caribbean Expedition; 178 lots, 1,225 specimens, of marine, fresh-water, and land mollusks from Chile, a gift of Dr. Walter Riese; and 279 lots, 521 specimens, of marine mollusks from Mozambique, purchased through the Frances Lea Chamberlain fund.

The division of marine invertebrates received 7,685 specimens collected by the Bredin-Smithsonian Caribbean Expedition. Dr. R. E. Coker donated over 3,400 crustaceans, largely copepods, and Dr. T. E. Bowman presented his collection of 7,154 miscellaneous invertebrates. Type material was included in the following gifts: 397 copepod crustaceans from Dr. Arthur G. Humes; 8 hermit crabs, including 3 paratypes of three species from Anthony J. Provenzano; and 3 paratypes of a species of an ostracod crustacean from Dr. Eugene W. Kozloff. One small accession, a gift from R. P. Higgins, of the holotype and two paratypes of a species of *Echinodera* added the first representatives of this little-known phylum of the Animal Kingdom to the national collections.

Civil history.—Several gifts enhanced the furniture collection in the division of cultural history. A Louis IV commode with marble top, labeled with the maker's name, "M. Cresson," was given by Mr. and Mrs. William W. Wickes, and a painted Tyrolean wardrobe on frame was presented by the estate of Dr. Elisabeth Lotte Franzos. Mrs. H. B. Blackmar gave a Connecticut cherry "highboy," an Empire sofa, and several chairs; Mr. and Mrs. Louis Rothschild donated an American secretary-bookcase, a chest of drawers, and a card table, all late 18th century; and Mr. and Mrs. Edmund C. Monell presented several examples of Chinese lacquered furniture.

Three outstanding acquisitions of architectural importance were made this year. An entire room and numerous fragments were obtained from the Gothic Revival-style Harral-Wheeler house in Bridgeport, Conn., designed by Andrew Jackson Davis about 1848. The material was given by the city of Bridgeport upon dismantling. A wide variety of cast-iron architectural fragments from office buildings and store fronts of the now-demolished old mercantile section of St. Louis was transferred by the Jefferson National Expansion Memorial of the National Park Service. An entire loghouse, built in Wilmington, Del., in the German tradition in the late 18th century, was given by the Board of Trustees and Building Commission of the Henry C. Conrad School Department of Wilmington. Other gifts include a pair of 18th-century wine coolers used in the Winter Palace of St. Petersburg and a silver tea and coffee service originally owned by Czar Alexander I from Col. William E. Shipp, an American Empire-style silver tea and coffee service from Mrs. Mary A. Swanton, and a Pennsylvanian stove plate, dated 1784, from the Union Fork & Hoe Co.

The division of political history received important new additions to the White House china collection. Henry Francis Du Pont donated a dessert service purchased for the White House during the administration of Monroe. The china has an amaranthine border with vignettes representing military might, agriculture, commerce, art, and science, and was made in France by Dagoty. Outstanding accessions to the collection of American period costume were an early dress of homespun cotton, given by Mrs. Charles D. Collins; a dress and wedding petticoats of the early 19th century, a gift of the Misses Marion and Elinor Abbot; a collection of late 19th- and early 20th-century costumes, presented by Miss Eleanor P. Custis; and a wedding dress and other costumes of the 1890's of historic importance because of their connection with famous South Carolina families, the gift of Mrs. Pinckney Alston Trapier. A flag which had been hung out in mourning at the time of Lincoln's death was donated by John M. Harlan, Associate Justice of the Supreme Court.

The donation of Mrs. Catherine E. Bullowa, consisting of 21,531 coins, medals, and paper currencies, is an important addition to the numismatic collection. Of special interest in this series is a group of 504 early German and Italian silver and copper coins, dating from the 11th through the 16th centuries, and a collection of 62 German patterns engraved by C. Goetz at the Munich Mint after World War I. Another noteworthy accession is the President Dwight D. Eisenhower collection of coins, medals, and memorabilia, including a group of 149 gold, silver, and copper mintings covering all periods of history from Ancient Greece to modern times. Especially remarkable are the silver shekel from Judea struck during the first revolt against the Romans in A.D. 66-70 and a silver shekel from Tyre, Phoenicia, considered similar to the "thirty pieces of silver" of the Bible. A set of 14 gold medals issued by the Italo-Venezuelan Bank portraying World War II leaders and a 20-dollar gold piece engraved on the reverse "Reims, May 7, 1945, 0240" are part of a group of coins bearing special dedications to President Eisenhower.

A collection of nine medals and plaques engraved by the American medalist Victor D. Brenner was received from the Eric P. Newman Numismatic Education Society of St. Louis. An important collection of 307 proclamation pieces, struck by different Mexican cities and organizations in the late 18th and early 19th centuries in commemoration of the late Spanish kings, was presented by Joseph B. Stack.

Former Postmaster General James A. Farley converted two additional units from loan to gift in the division of philately and postal history, thus concluding the transaction begun in 1956. Two collections of inestimable reference value were transferred from the Library of Congress—the Ackerman collection of U.S. die and plate proofs in

three volumes features postage, and the Clarence H. Eagle collection of U.S. revenue proofs and essays includes a comprehensive showing of match and medicine varieties. John P. V. Heinmuller donated his prize-winning collection of Zeppelin covers. Housed in 21 volumes, the collection portrays the early experimental flights of the 1908-10 period, World War I, and all flights of the Graf Zeppelin. One interesting specimen is a scorched cover carried on the ill-fated flight of the Zeppelin *Hindenberg*, which burned at Lakehurst, N.J., May 6, 1937. Comdr. W. R. Anderson, Commanding Officer, U.S. Navy submarine *Nautilus*, presented in the name of the Navy and his crew the rubber canceling devices made by the crew members and used to cachet envelopes in commemoration of the first navigation by submarine beneath the polar icecap.

Armed Forces history.—Among the outstanding material received in Armed Forces history were early U.S. military and naval insignia from the unique W. Stokes Kirk collection, a very rare pair of epaulets owned by Gen. George Washington acquired from Mrs. Janet Randolph Ball Haden, and an early 19th-century broadax from the Fort Ticonderoga Museum. Transferred from the U.S. Naval Academy were 17 builders' half models of early naval vessels, and examples of diving gear were received from the Experimental Diving Unit, Department of the Navy.

Original drawings numbering 177 of plans for U.S. sailing ships were presented by Howard I. Chapelle, author of the important work "The History of the American Sailing Navy." Frank Mather Archer presented an excellent example of the type of uniform coat worn by a lieutenant of the U.S. Infantry during the period of 1828-36. An outstanding collection of prints and books illustrating European uniforms and equipment was presented by Col. William E. Shipp. Edward B. Tucker of Somerset, Bermuda, donated objects recovered from 16th- and 19th-century shipwrecks. Collections of objects recovered from 18th-century shipwreck sites in Florida were received through the courtesy of Edwin A. Link, Arthur McKee, and Dr. and Mrs. George Crile, Jr. An iron shot from the site of the 16th-century fortress of San Lorenzo was given by Karl P. Curtis of Panama.

Arts and manufactures.—An outstanding addition to the division of ceramics and glass is a collection of 600 pieces of Dutch and German pottery and stoneware, the gift of the Honorable Wiley T. Buchanan, Jr., Chief of Protocol, and Mrs. Buchanan. The collection is especially rich in Medieval Dutch household wares and Rhenish stoneware types, many of which are exhibited nowhere else in the United States. A noteworthy slip-decorated Rhenish jar from Pingsdorf, Germany, dated 12th or 13th century, is representative of the beginnings of the very important German stoneware industry. A ewer from Rheren

dated 1585, in almost perfect condition, is exceptional in that most wares of this type lack the spout or handle or both. The collection of 170 glass items donated by Mrs. Clara W. Berwick includes a rare group comprising early American glass pieces of Stiegel and Amelung type, as well as later wares from the famous Sandwich factory in Massachusetts. Mrs. Mary Roebling gave three sculptured birds and the figures of horses by Edward Marshall Boehm. Mrs. George Hewitt Myers presented 48 pieces of Castleford porcelain made in England between 1790 and 1820. Among these rare items are teapots and pitchers decorated with an American eagle after the design of contemporary coins.

The division of graphic arts acquired an important group of fine prints. The selection of these examples by outstanding printmakers from the year 1500 to the present day made it possible to fill a number of significant gaps in the collection. The prints include an engraving by the Italian Renaissance master Marcantonio Raimondi, "St. Cecilia"; two prints by important French artists of the turn of the 20th century—a lithograph by Edouard Manet, "La Barricade," and a color lithograph by Edouard Vuillard, "Les Deux Belles Soeurs"; and an exceptionally fine impression of an etching by Rembrandt van Rijn, "Landscape with a Flock of Sheep." A 50-line halftone screen was presented by Max Levy & Co., Philadelphia, through Howard S. Levy; R. R. Donnelley & Sons Co., Chicago, through Walter L. Howe, gave a panel describing the rotogravure process; and the firm of Edgerton, Germeshausen & Grier, Inc., Boston, donated the first battery-operated portable electronic flash unit, invented by Dr. Harold E. Edgerton.

The division of textiles received from Arthur E. Wullschleger an 18th-century French hand-and-foot treadle loom to which a Jacquard head had been added in the 19th century. Mr. Wullschleger obtained the loom in Lyons, France, and it was renovated at Wedgewood Mills, Jewett City, Conn. An excellent model of the 1787 patent of Cartwright's power loom, an invention unrepresented in the national collection, was made by Robert Klinger of the exhibits staff. A fine collection of 46 18th- and 19th-century printed cottons was given by Mrs. Kenneth Franzheim. Beautiful examples of contemporary hand- and power-woven fabrics were presented by the Irish Linen Guild, Potomac Craftsmen, Designer-Weavers, the American Cotton Manufacturers Institute, the Corduroy Council, the International Silk Association, and the Man-Made Fibers Association.

The division of industrial cooperation received the original equipment used in 1956-57 to carry out the experiments suggested by Nobel prize winners Dr. T. D. Lee of Columbia University and Dr. C. N. Yang of the Institute for Advanced Studies to demonstrate that in

the decay of an elementary particle into another particle parity is not conserved. Examples of early seismometers used in exploration for oil were presented by the Continental Oil Co.

Science and technology.—The most noteworthy accession acquired in the division of agriculture and wood products comprised 111 authentic wood samples of Santa Catarina, Brazil, collected and donated by Dr. Lyman B. Smith. A portable farm steam engine made in 1877 by Frick & Co. was donated by this firm.

Among the pieces of major importance added to the division of electricity are the following: A group of pieces constructed by Thomas Davenport, a Vermont blacksmith who obtained the first patent on an electric motor, given by Frank Chandler; and from the General Electric Research Laboratory, replicas of Dr. Irving Langmuir's vacuum distillation pump and of his apparatus for measuring surface tension which was basic to the work for which he received the Nobel prize. Mrs. Edith Earle donated two examples of the telephone that her father, James H. Earle, made in the winter of 1876-77 at Brown University under the direction of a group of professors there. The acoustical design of the group at Brown was incorporated in the design of the Bell telephone.

The following significant objects were acquired in the division of mechanical and civil engineering: The personal watch of Edward Howard, considered the parent of all American factory-made watches, from the Massachusetts Charitable Mechanic Association; a rare and fine wagon-spring clock given by Mrs. Francis Boutelle Allen; and three noteworthy precision clocks presented by the Georgetown University Observatory through Father F. J. Heyden. A valuable and attractive collection of early handmade locks, bolts, and decorative hardware, with pieces dating from the 16th century, was presented by the Yale & Towne Manufacturing Co. Two important early machine tools were received—an 1851 Robbins and Lawrence chain-feed lathe given by Curtis Woodruff, and a Jones & Lamson turret lathe of about 1880 donated by George F. Kiley. A Porter-Allen steam engine, prototype of the compact high-speed steam engine which dominated the medium-size engine field for many years, was presented by the Philadelphia Electric Co.

The most significant acquisition in the division of medical sciences is a collection of dental instruments, furniture, and equipment relating to the history of dentistry, totaling 2,869 specimens, received from the University of Pennsylvania School of Dentistry. This provides an excellent cross section of the equipment used by the dentist from the mid-19th century until the early 20th century, containing rare individual items such as an early ether inhaler and two extraction instruments. An important collection of material relating to the dis-

covery and development of the Salk poliomyelitis vaccine was contributed by the National Foundation for Infantile Paralysis. This collection includes original flasks used by Dr. John F. Enders to grow polio viruses in cultures of human embryonic skin and muscle tissue; a bottle and automatic rocker used at the University of Toronto Connaught Laboratories to grow polio virus in quantity; syringe and residues of the first vaccines given by Dr. Jonas E. Salk; and the original draft of the report by Dr. Thomas Francis, Jr., evaluating the 1954 field trials of poliomyelitis vaccine.

The division of physical sciences continued its efforts to acquire early scientific apparatus used in colleges. The majority of the apparatus collected this year is chemical, and the most noteworthy accession is a group of instruments used by Ira Remsen at Johns Hopkins University. Other outstanding items obtained are the first equatorial telescope (1876) of the Warner & Swasey Co., the gift of that firm, and the first helium liquefier built in the United States in 1931 donated by the National Bureau of Standards.

Specimens of major importance acquired in the division of transportation are a model representing the sister ships *Independence* and *Constitution*, modern American liners, received from American Export Lines, and the models of the Hudson River steamer *Francis Skiddy* from F. Van Loon Ryder and the Narragansett Bay steamer *Mount Hope* from Mary T. Campbell. Other outstanding accessions include an oil-tank wagon from the Esso Standard Oil Co., a private coach, presented by Mrs. Richard Saltonstall through the interest of Senator Leverett Saltonstall, and a Conestoga wagon from Howard C. Frey. The private coach, a most significant addition, was built in 1851 by the famous carriage maker Thomas Goddard of Boston.

EXPLORATION AND FIELDWORK

The department of anthropology has underway an extensive program to revitalize the famous paintings of Indians by George Catlin. F. M. Setzler, head curator, went to Boston between May 26 and 28, 1959, to investigate the progress of the renovations, which are being carried out under the guidance of Henri Courtais. Cleaning the painted surfaces involves a variety of methods and chemical solutions, depending on the condition of the painting and the canvas. A large percentage of the original Catlin paintings had been relined with a canvas about 75 years ago, when someone repainted the backgrounds of most of the paintings involved. This repainting was done on top of dirt, smoke, and water blemishes. The overpaint requires additional time and effort to remove before Mr. Courtais and his assistants can clean the original painted surface. After this overpaint is removed, the excellence of the painting can be truly appreciated and

furthermore the garments, feathers, and Indian and European ornaments as depicted by Catlin can be readily identified. Mr. Courtais is continuing his work, and it is hoped that the entire program will be completed within the next 2 or 3 years.

Between January 18 and 20, 1959, Dr. Waldo R. Wedel, curator of archeology, visited the Metropolitan Museum of Art in New York City to examine duplicate Egyptian antiquities with a view to obtaining objects suitable to our exhibits program. With the aid of Mrs. Virginia M. Pollak, Dr. Wedel selected 33 items for purchase. These include several reliefs, two baskets, a bedstead and stool, a wooden hawk case with hawk mummy, and a bronze hawk and small bronze mummy case. Practically all these will be suitable for exhibit and will provide displays that do not now exist in our Egyptian collections. Early in May, following the annual meetings of the Society for American Archeology in Salt Lake City, Utah, Dr. Wedel devoted several days to examination of the collections of the University of Utah Museum, with particular reference to materials that are related to Western Plains cultures. He also visited Ogden, Utah, where he examined an unusual collection, including many stone bowls and manos and a considerable variety of projectile points and stone ornaments. The material acquired will be useful for exhibit and study purposes.

Between July 7 and September 20, 1958, Dr. Clifford Evans, associate curator of archeology, and Dr. Betty J. Meggers, honorary research associate, visited Panama, Costa Rica, and Ecuador. They spent 4 days in Panama City examining collections in the Museo Nacional and discussing problems of museum modernization with the director. They also discussed in detail the possibilities of collaborative research, using the services of H. Morgan Smith, involving archeological sites now being discovered or destroyed by road or building construction. Subsequently Mr. Smith was appointed a collaborator of the Smithsonian Institution.

Between July 19 and July 28, Drs. Evans and Meggers participated in the 33d International Congress of Americanists at San José, Costa Rica. This very successful meeting was attended by a large representation of scientists from Latin America, North America, and Europe. The Smithsonian Institution representatives participated in several important symposia dealing with the problem of the Formative Period in Mesoamerica and South America, in addition to delivering a scientific paper on the preliminary results of their archeological investigations in the headwaters of the Orinoco. At this meeting, Middle American and South American specialists decided that a coordinated program of research toward a solution of a specific problem will produce better results than individual research projects. A

committee was appointed to organize research centering on the importance of Mesoamerican and northern South American connections from the Formative Period up to Spanish Contact, and Dr. Evans accepted the secretaryship of this committee.

Proceeding to Guayaquil, Ecuador, on July 28, Drs. Evans and Meggers continued their archeological research in cooperation with Emilio Estrada, Director of the Museo Arqueológico "Victor Emilio Estrada." This research was principally directed toward filling in certain gaps in the sequences that have been worked out in the past 5 years by Estrada, Evans, and Meggers for the south coast. It is felt that progress toward the solution of this problem is now being made. On their return trip Drs. Evans and Meggers stopped briefly in New Orleans and visited specialists at Tulane University. In March 1959, Dr. Evans examined collections at the Heye Foundation in New York City to study important material referring to coastal Ecuador; many photographs were taken which will serve as a basis for future study.

Dr. Ralph S. Solecki, associate curator of archeology, visited University Park and Philadelphia, Pa., between September 15 and 19, 1958. At Pennsylvania State University he consulted with staff members about fieldwork in the Near East and viewed the ceramic collections made by Dr. Dupree and Dr. Matson of the State University staff, in connection with the material recovered by the Smithsonian Institution Shanidar project. At the University Museum at Philadelphia, Dr. Solecki conferred with staff members concerning fieldwork in Iran and Iraq. A general survey of the Old World archeological collections was made in order to ascertain what materials are lacking in the Smithsonian collections.

During the period March 15 to April 8, 1959, Dr. Solecki was detailed to participate in a UNESCO meeting in Paris, called to discuss measures to minimize the unfavorable effects of large-scale engineering works upon items of cultural interest as well as upon the ecological conditions of the regions affected. Dr. Solecki conferred with the Secretariat of UNESCO and the Bureau of the International Committee on Monuments on matters of procedure regarding the problem. He prepared a summary statement of the problems involved and suggested solutions, and subsequently participated in a regular meeting of the Bureau of the International Committee on Monuments on April 2. In Paris, and also in London, Dr. Solecki visited several museums and scientific institutions to arrange possible archeological exchanges between these institutions and the Smithsonian Institution.

From December 1 to 14, 1958, Dr. S. H. Riesenbergs, curator of ethnology, visited the Peabody Museum, Salem, Mass., and Harvard University. He continued his study of Micronesian ethnographical collections at the Peabody Museum and also examined and abstracted

pertinent Caroline Islands materials from important collections of early American ships' logs, journals, and manuscripts of early voyages contained in the archives of that museum and the Essex Institute. Parallel studies were made in the Harvard Peabody Museum and in the Houghton Library of Harvard University, where many pertinent ethnohistorical manuscript records of the American Board of Commissioners for Foreign Missions are housed. Such museum and library studies are aiding Dr. Riesenbergs in his projected analysis of Micronesian material culture, which is an attempt to place Micronesia in its proper ethnological position with respect to Pacific island cultural development and history. A trip for the same purposes was made by Dr. Riesenbergs to the Chicago Natural History Museum between March 9 and 13, 1959. At this important museum he examined and studied the collections of important ethnographical materials from the Caroline and Marshall Islands.

In continuation of his African studies, Dr. Gordon D. Gibson, associate curator of ethnology, spent the week of May 18 to 23, 1959, examining ethnological materials from Angola in the collections of the Chicago Natural History Museum and in conferring with staff members with respect to the identification of African specimens in our collections, certain problems of museum display, the possibility of exchanging specimens, and problems connected with his research. The Chicago Natural History Museum has probably the largest collection of Angolan ethnological materials in the United States, and therefore the opportunity to study these materials at firsthand was a significant aid to the progress of Dr. Gibson's research on the ethnology of the southwestern Bantu.

In the latter part of July and early in August 1958 Dr. T. Dale Stewart, curator of physical anthropology, visited several countries in Central America. Together with Dr. Evans and Dr. Meggers, he visited the National Museum in Panama, where, as indicated above, the Smithsonian Institution party was very well received. They made a brief trip to the San Blas Islands on the Atlantic side of the Isthmus, in order to see firsthand the San Blas or Cuna Indians living thereon. These Indians have kept themselves pureblooded and therefore offer opportunities for research. Dr. Stewart also attended the 33d International Congress of Americanists in San José, Costa Rica. Like Drs. Evans and Meggers, he was asked to act as chairman at one of the sessions, and in addition he read an invited paper. It is felt that the Smithsonian Institution staff has been and still is at work in a critical area for the solution of problems referring to prehistoric cultures of Central America and the coast of Ecuador.

Following the congress, Dr. and Mrs. Stewart went north to Guatemala, where they were joined by about 20 anthropologists. On

August 1, as guests of the Guatemalan Government, they were flown into Tikal, a great Mayan ruin being excavated and restored by the University of Pennsylvania. The travelers also made a quick trip to Lake Atitlán and to Chichicastenango. Because of his work on the living Indians in this area in 1947 and 1949, Dr. Stewart was interested to observe the rate of acculturation here. As far as he could judge, there was very little change since his last visit. In Mexico City Dr. and Mrs. Stewart called at the National Museum and subsequently examined some promising fossil sites in the Valley of Mexico, where a new excavation is being made and a human skull was found at the Pleistocene level. During the visit to Mexico City Dr. Stewart obtained considerable information that will be of use to him in working for the Handbook of Latin American Studies and the projected Handbook of Middle American Indians.

Between March 25 and April 13, 1959, Dr. Stewart was detailed to travel to Czechoslovakia to act as the official U.S. representative at ceremonies honoring the 90th birthday of the late Dr. Aleš Hrdlička, who for so long was curator of physical anthropology at the Smithsonian Institution. At formal ceremonies in Prague, Dr. Stewart had the opportunity to stress the fact of Hrdlička's American citizenship. In his address to the delegates he was able to point out that only in America could Hrdlička have achieved his fame as an anthropologist. Later the celebration moved to Humpolec, Hrdlička's birthplace, 80 or 90 miles from Prague. Here Dr. Stewart and other delegates were taken through the local high school, which has been renamed for Hrdlička. They also visited the site of his home, saw the street named for him, and visited various local institutions. At a celebration Dr. Stewart again had an opportunity to say something about Dr. Hrdlička's life in America and the opportunity for scientific research in this country. On March 31 he participated in scientific meetings at the Institute of Anthropology at Charles University in Prague, on this occasion giving the delegates a report of his study of the Shanidar skeleton. This visit to Prague gave Dr. Stewart an opportunity to meet several of his colleagues whom he has previously known by correspondence. On his return trip Dr. Stewart made a brief stop in Zurich to visit the Anthropological Institute. In London he visited the British Museum to examine the Mount Carmel Neanderthal remains, this visit providing him with a very profitable 2 days of research.

In March 1959 Dr. Lyman B. Smith, curator of phanerograms, visited Cambridge, Mass., to study Herbarium material and to verify bibliographic references in the Harvard Herbarium in connection with his research on the family Bromeliaceae and the flora of Santa Catarina, Brazil.

Dr. Richard S. Cowan, associate curator of phanerogams, visited the Gray Herbarium of Harvard University and the New York Botanical Garden in November 1958 in connection with his work on the *Index Nomina Genericorum*, the flora of Santa Catarina, and plants of the Guyana Highland. At the second of these institutions he conferred with Drs. Maguire and Wurdack for the purpose of outlining in a general way the structure and content as well as the geographic limits of the proposed Flora of Guyana. Dr. Cowan also represented the department of botany on the 1959 Smithsonian-Bredin Expedition.

In connection with her continuing studies of *Ormosia* and other genera of the family Leguminosae, Dr. Velva E. Rudd, associate curator of phanerogams, visited New York and Philadelphia in November and Chicago in December 1958. At the New York Botanical Garden, the Academy of Natural Sciences of Philadelphia, and the Chicago Natural History Museum she surveyed the available study materials in groups of interest to her, and selected specimens for borrowing.

Between August 20 and 24, 1958, C. V. Morton, curator of ferns, participated in the annual summer foray of the American Fern Society in southern Ohio, after which he attended the meetings of the American Institute of Biological Sciences at Indiana University. In November and December he studied in the herbarium and library of the Harvard University Herbarium in Cambridge in order to check the bibliographical citations for the *Index Nomina Genericorum*. In connection with the same project he also visited the New York Botanical Garden.

In July 1958 Dr. Mason E. Hale, associate curator of cryptogams, spent several days in southwestern Virginia and the adjacent area of Tennessee in company with R. R. Ireland, assistant curator of cryptogams, in pursuance of his fieldwork on Appalachian lichens. This study, undertaken with the aid of a grant from the National Science Foundation, has resulted in the collection of many specimens of lichens in the area. In February 1959 Dr. Hale spent several days in the cryptogamic herbarium of Duke University, examining lichens in the very important Harmand Herbarium with particular reference to the study of the lichen flora of the central Appalachian Mountains. In May he continued his work on the same project by studying in the rich cryptogamic library and herbarium of Harvard University.

Dr. Herbert Friedmann, head curator of the department of zoology, spent the period between July 7 and 26, 1958, in England, principally to attend the 15th International Congress of Zoology in London and a colloquium on zoological nomenclature. The congress, attended by

more than 1,900 zoologists from all over the world, marked the centenary of the first announcement of the theory of evolution by natural selection by Darwin and Wallace. Dr. Friedmann presented a paper on some of his current work on wax digestion in honeyguides and its microbiological implications. In October 1958 Dr. Friedmann represented the Museum of Natural History at a conference bringing together the directors of systematic collections, held at the New York State Museum in Albany.

On January 21, 1959, Dr. Alexander Wetmore, honorary research associate and retired Secretary of the Smithsonian Institution, returned to Panama to continue the survey of the birdlife of the Isthmus. The first few days, at Juan Mina, on the Río Chagres, he devoted to study of limpkins, tropical yellow rails, least bitterns, and other water birds concerning which little information has been available. On February 6 he left Panama City for El Real in eastern Darién, where, through the kind assistance of Frank L. Greene, resident manager of the oil company, Panamanian Delhi Petrolera, Inc., in Panama City, and Heinz Meyer, in charge at El Real, storage for part of the field outfit and other facilities were made available. On February 9 he continued by dugout canoe (piragua) up the Río Tuira and the following day reached the point where the Río Paya, which has its headwaters in Colombia, enters the larger stream. This is a region of high forest with few small, scattered clearings, made by Chocó Indians or an occasional pioneer settler from elsewhere. Tropical-zone forest birds were present in great variety of species, but so widely scattered through the vast forests of huge, tall trees that much search was required to find the more unusual kinds. Many are of South American affinity, as there is only a low divide between the upper Paya drainage and the lower Atrato Basin of northwestern Colombia. The collections and notes obtained here were thus of especial importance.

On March 18 Dr. Wetmore returned to El Real, to continue by dugout the following morning up the Río Chucunaque in company with the engineer, William Sun, to a camp of the oil company above the mouth of the Río Tuquesa. This also is a region of vast primitive forest, with a few Indian families living along the streams. Birds were common, with numbers of unusual kinds not found on the Tuira, so that the work here added much of value, particularly since the region worked between the Tuquesa and Ucugantí Rivers was one that scientifically had been unknown. In addition, there was the advantage of the engineer camp, with its small screened houses, electric light at night, and other facilities. The work closed on April 3 with return to El Real and from there to the Canal Zone on April 6 and to Washington on April 14.

During April and early May 1959, three members of the staff of the Museum of Natural History accompanied the 1959 Smithsonian-Bredin Caribbean Expedition, made possible through the generosity of Mr. and Mrs. J. Bruce Bredin, of Wilmington, Del. This was the fifth of a series of expeditions organized by Mr. Bredin in collaboration with the Smithsonian Institution, and the third in which he has personally taken an active part. As on the previous expeditions, Dr. Waldo L. Schmitt, research associate, was in charge of field operations. The other Smithsonian scientists participating were Dr. Thomas E. Bowman, associate curator of marine invertebrates and specialist on copepods, and Dr. Richard S. Cowan, associate curator of phanerogams. Dr. Cowan left in advance of the other members and spent the period between March 19 and April 2 on the island of Trinidad, where he made headquarters at the Imperial College of Tropical Agriculture, near Port-of-Spain. Excellent facilities provided by this college enabled him to reach several areas in Trinidad from which our department of botany had only limited collections heretofore.

The expeditionary party included, besides Mr. Bredin, John Finlay of Varadero, Cuba, expert malacologist; Dr. Richard F. Darsie, Jr., entomologist of the College of Agriculture of the University of Delaware, especially interested in tropical mosquitoes and their life histories; and William H. Amos, head of the science department of St. Andrews School, Middletown, Del., photographer to the expedition. They departed from Port-of-Spain, Trinidad, on the yacht *Caribee* on April 3 for the island of Tobago. Following several days of intensive work on the famed Bucco Reef off the west side of Tobago, where they obtained valuable invertebrate material, and a visit to the bird-of-paradise sanctuary on Little Tobago, the party made brief stops at Dominica, St. Lucia, Montserrat, Barbuda, and Antigua, where the labors of the expedition were concluded on May 5. Most interesting specimens of reef fishes were obtained off the windward side of Barbuda. On this island a series of caves explored by earlier Smithsonian-Bredin expeditions had yielded several unknown species of crustaceans, of which more extensive material was much desired; supplementary specimens were taken in traps carried along this year for the purpose. Many bats inhabiting a large cave on Antigua were captured primarily for a study that Dr. Darsie wished to make of their ectoparasites. This third trip to the Lesser Antilles sponsored by Mr. and Mrs. Bredin has still further enhanced the collections of the Smithsonian Institution from that important area, in which still further undescribed species of marine life have been discovered.

Dr. Charles O. Handley, Jr., associate curator of mammals, spent December 1 to 12, 1958, visiting the Academy of Natural Sciences of Philadelphia, the Museum of Comparative Zoology at Harvard University, and the American Museum of Natural History in New York to study types and other specimens pertinent to research projects in progress. Accompanied by Bernard R. Feinstein, museum aide in the division of birds, Dr. Handley continued his mammal survey of Panama between January 15 and March 27, 1959, working in the portion of Darién adjacent to the Colombian boundary. Members of the party reached mountainous areas where zoologists have not previously collected. As a result of the trip, collections totaled more than 1,500 mammals and several hundred birds, reptiles, and various insects and other animals. Conditions for netting bats were especially good, and new techniques were developed. No fewer than 45 species of bats were obtained, possibly a record high for this country. It is planned to continue this project, which is sponsored by the Gorgas Memorial Laboratory, Panama. In continuation of his research on the mammal fauna of the southeastern United States, Dr. Handley spent two periods collecting in Virginia in May 1959. One of these trips took him to the peninsulas on the west side of Chesapeake Bay and the other to some of the northernmost ridges of the Great Smoky Mountains. The mammal specimens preserved on these trips will add to the background material for his continuing research.

Between March 18 and 23, 1959, Herbert G. Deignan, associate curator of birds, visited England, primarily to participate in the centenary celebration of the British Ornithologists' Union, which was held at Cambridge. The meetings were largely devoted to series of symposia on various aspects of ornithology.

Dr. Ernest A. Lachner, associate curator of fishes, attended the annual meetings of the American Institute of Biological Sciences in Bloomington, Ind. While there he examined the fish collections of the university and on the return trip to Washington studied the fish collection at the University of Louisville. Dr. Lachner was accompanied by Dr. William R. Taylor, associate curator of fishes. On their return east the two ichthyologists made collections in streams draining Kentucky, West Virginia, and Virginia.

Between November 3 and 8, 1958, Drs. Lachner and Taylor made a trip to the University of South Carolina to prepare and pack major portions of the fish collection of that institution for shipping to the Smithsonian Institution. This valuable collection, consisting of about 25,000 specimens, is composed of preserved material that is sure to be very useful for future group revisionary studies, especially since it comes from an area of the country not too well represented in the national collections. On the return trip Drs. Lachner and Taylor

collected at an important locality in North Carolina and also visited the Marine Laboratory at the University of North Carolina, Morehead City, and the U.S. Fish and Wildlife Service Laboratory at Beaufort, N.C.

With the aid of a grant from the National Science Foundation, Dr. J. F. Gates Clarke, curator of insects, made a trip to South America between December 29, 1958, and March 24, 1959, the major purpose of which was to obtain material of Microlepidoptera in localities not otherwise represented in the collections of the Smithsonian Institution. Dr. Clarke traveled widely in Colombia, making headquarters at Bogotá, Cali, Popayán, Pasto, and Barranquilla. In Peru Dr. Clarke centered his work in Lima and Cusco, from which cities he was able to reach interesting collecting territory. A brief stop was made in the area of Santa Cruz, Bolivia, and then he proceeded to Argentina, making his principal headquarters at Tucumán. While at Tucumán Dr. Clarke prepared the valuable Monrós collection of chrysomelid beetles for shipment to the National Museum. This collection adds greatly to the value of the holdings of South American insects in the Smithsonian Institution. He spent the latter part of his visit in Chile, collecting in the southern part of the country in areas reached from Punta Arenas, Puerto Varas, Peulla, and Petrohue. Dr. Clarke collected about 15,000 specimens of insects of all groups, but particularly of the Microlepidoptera, which will serve as the major basis of his proposed revision of the South American species of this large and important group.

Between May 9 and June 4, 1959, Oscar L. Cartwright, associate curator of insects, engaged in field research in Florida to collect Scarabaeidae, especially species of *Onthophagus* and *Ataenius*, genera he is at present revising. The trip traversed peninsular Florida as far south as Big Pine Key. Of the 2,356 insects collected, few have yet been identified to species, but there are among them new records for Florida and the United States and quite possibly some undescribed species.

Dr. Ralph E. Crabill, Jr., associate curator of insects, spent the period July 14-18, 1958, in Cambridge, Mass., carrying on studies at the Museum of Comparative Zoology in connection with several research projects in chilopod systematics.

Dr. Frederick M. Bayer, associate curator of marine invertebrates, visited Europe between July 17 and August 25, 1958, to attend the 15th International Congress of Zoology in London and to visit several European museums for the purpose of evaluating the significance of their collections of octocorals to future studies and to examine specimens. Following the congress he visited museums in Leiden, Amsterdam, and Copenhagen, as well as the British Museum (Natural His-

tory) in London, and had an excellent opportunity to study important historic collections in the field of his speciality.

In addition to participating in the Smithsonian-Bredin Caribbean Expedition discussed earlier, Dr. Thomas E. Bowman, associate curator of marine invertebrates, visited Puerto Rico for 2 weeks in early April 1959, at the request of Dr. Robert M. Coker, who is directing a study of the zooplankton of the bays along the southwestern coast. With headquarters at the Institute of Marine Biology, Dr. Bowman made extensive collections that will materially assist him in his project of identification of the copepods of the region.

Dr. Harald A. Rehder, curator of mollusks, spent the week of February 16-23, 1959, in Florida, primarily to act as one of the judges of the annual show of the St. Petersburg Shell Club. The Smithsonian Institution offers an annual award for the best exhibit in this show. Subsequently he visited the Marine Laboratory of the University of Miami, where he observed some of the current studies of staff members of level bottom marine invertebrate communities along the south Florida coast.

Dr. G. A. Cooper, head curator, department of geology, accompanied by Dr. Richard S. Boardman, associate curator of invertebrate paleontology and paleobotany, spent the period May 18-30, 1958, on a field trip to central New York. They were accompanied by Dr. Gertrude Biernat, of Polska Akademia Nauk, Zaklad Paleozoologii, Warsaw, Poland, a visitor to the museum for several months, and by two members of the Geological Survey staff. They spent several days studying and collecting from the type section of the Hamilton group of the Devonian, which extends from Stockbridge Falls on the north to North Norwich on the south. The party was joined by other geologists, including Dr. Paul Sartenaer, of Belgium, and members of the staff of the New York State Museum, and with this company a study of the facies changes which take place in the Tully formation was made. Subsequently sections were examined in the area of Cooperstown, Cobleskill, Albany, Kingston, N.Y., and Stroudsburg, Pa. Following this trip Dr. Boardman spent a few days at the New York State Museum at Albany to investigate the possibility of identifying bryozoan fragments in well cuttings in the Middle Devonian in New York State.

During August 1958 Dr. George Switzer, curator of mineralogy and petrology, made an extended collecting trip to western localities, particularly to various individuals and well-known localities in Iowa, Colorado, New Mexico, California, and Montana. He obtained much material of value to the Smithsonian for purposes of study or exhibit. Accompanied by Paul E. Desautels, associate curator of mineralogy and petrology, Dr. Switzer made several other trips for the purpose

of visiting mineral dealers and obtaining material for the Smithsonian collections. Short visits were made to the American Museum of Natural History in New York and the Academy of Natural Sciences of Philadelphia; a valuable collection of minerals from the famous zinc mine at Franklin, N.J., was examined and purchases from it were made for the Smithsonian collections. During August 1958 and March 1959 Mr. Desautels made separate trips to Asheville, N.C., and to several cities in Pennsylvania, New Jersey, and Massachusetts to acquire and examine mineralogical specimens for the Museum.

E. P. Henderson, associate curator of mineralogy and petrology, spent the period November 30–December 10, 1958, in Boston, New Haven, and New York. He discussed meteorites with members of the staffs of the Massachusetts Institute of Technology, Harvard University, Yale University, and the American Museum of Natural History.

In addition to participating in the field trip to New York State discussed above, Dr. Richard S. Boardman traveled in Tennessee and southern Virginia between September 22 and October 24, 1958, in the company of two visiting paleontologists, one from Australia and one from Norway. The principal objectives were to study the regional stratigraphy and to collect Bryozoa in the Middle Ordovician rocks of the Central Basin area of Tennessee and the southern Appalachians of eastern Tennessee and southern Virginia. This preliminary survey will form the basis for planning a continuing program in the largely unstudied bryozoan faunas of the Middle Ordovician of the region. Collections totaled 2,500 pounds and include many bryozoan colonies that have biological and taxonomic interest in addition to their potential stratigraphic value.

In connection with his work on fossil echinoids, Dr. Porter M. Kier, associate curator of invertebrate paleontology and paleobotany, spent the period between July 19 and August 29, 1958, in Europe. Dr. Kier's trip was sponsored by a grant from the National Science Foundation. He spent several days in England examining specimens in the British Museum (Natural History) in London and the Sedgwick Museum in Cambridge and subsequently visited museums at the University of Liège and the Institute Royal des Sciences Naturelles in Brussels. In Paris he visited three museums where there are important collections of fossil echinoids. During part of his stay in Europe. Dr. Kier collected fossils in Belgium, Holland, and France in company with various specialists. Between March 9 and 13, 1959, he visited the Museum of Comparative Zoology at Harvard University to study the fossil echinoid collections. Several

valuable and overlooked European type specimens were found there, in addition to specimens that will subsequently be described as new species. Accompanied by Henry B. Roberts, museum aide, he made a field trip to Alabama and Florida, April 6-16, 1959. Collecting was particularly productive in the Ocala area.

Dr. C. Lewis Gazin, curator of vertebrate paleontology, visited Princeton University and the American Museum of Natural History in New York between November 16 and 23, 1958, to study their collections of lower Eocene primates and to make comparisons between lower Eocene Knight materials and various Eocene collections and type materials at those institutions. In June 1959 he made a further visit to these same institutions and also to Yale University, Amherst College, and Harvard University to study lower Eocene and Paleocene insectivores, primates, condylarths, creodonts, and related groups.

Dr. David H. Dunkle, associate curator of vertebrate paleontology, spent September 24-30, 1958, at the University of Kansas, studying their excellently curated collections of fossil fishes. In particular, he made anatomical observations upon an extensive series of sylvlaemid fishes. In May 1959 he visited the site of the new airport construction at Chantilly, Va., where he examined and collected some Triassic bones reported by a member of the U.S. Geological Survey staff. The bones have been tentatively identified as pertaining to a phytosaur, an extinct reptile quite crocodilian in appearance, distantly related to the dinosaurs. This specimen is believed to be the first such animal in the national collections from the Virginia Triassic.

Dr. Peter P. Vaughn, associate curator of vertebrate paleontology, made a trip to the University of Michigan and the Chicago Natural History Museum between September 1 and 14, 1958, to study Permian vertebrates in those important collections. Between October 6 and 13, 1958, he undertook a reconnaissance study in the Permian Cutler formation of southwestern Colorado. The information gained on this trip will be incorporated into a report on the fossil fauna of the region which he is preparing in collaboration with staff members of the Geological Survey.

The Director of the Museum of History and Technology, Frank A. Taylor, spent 2 days in September 1958 near Essex, N.Y., where he visited the site of a 1776 gunboat.

Dr. Robert P. Multhauf, head curator of science and technology, made several extensive field trips during the year for the purpose of examining new exhibits and inspecting or acquiring important apparatus to illustrate the development of the physical sciences. He visited many institutions and individuals in the San Francisco area, in the vicinity of New York, and in Baltimore, Philadelphia, Fred-

ericksburg, Va., and Lexington, Ky., and acquired many items of interest to the Smithsonian Institution exhibits and study collections. Among them were materials associated with Ira Remsen, the famous Johns Hopkins University chemist. At the Stevens Institute of Technology he examined the residues of the formerly extensive museum. These comprise about 100 items, mostly models of considerable importance. Of particular interest also was a visit to Transylvania College, in Lexington, Ky., where Dr. Multhauf examined a collection of early 19th-century "philosophical apparatus," which proved to be the most complete representation of instructional apparatus for a single period that has yet been located. There are about 150 pieces, all obtained between 1815 and 1839. Dr. Multhauf offered to give his advisory assistance to Transylvania College to carry out plans for the exhibition and study of these materials.

In continuation of his efforts to build up the exhibit and study materials pertaining to the division of mechanical and civil engineering, Eugene S. Ferguson, curator of that division, visited many individuals and institutions throughout the eastern United States, in Connecticut, Rhode Island, Pennsylvania, Ohio, Indiana, Michigan, and Wisconsin. Mr. Ferguson's most extensive trip, however, took him to various European countries between February 28 and April 13, 1959. During the 6 weeks that he spent in looking critically at European technical museums, he visited Great Britain, Sweden, Germany, Italy, Austria, France, and Holland, seeing altogether 31 museums. He acquired many impressions and ideas that will be useful in designing new halls in the Museum of History and Technology. In his opinion the best technical museum that he visited was the Deutsches Museum in Munich. It is extravagant in its use of space and dioramas, and of all museums he believes it to be the one that is most meticulous in the details of exhibit design and execution.

Edwin A. Battison, associate curator of mechanical and civil engineering, made several trips to various points in the eastern United States to examine clocks and other timepieces, particularly examples of early electric watch models and historic instruments. He visited many watch factories, with a view to the acquisition of material with potential value in the exhibits and study collections of the Museum of History and Technology.

Robert M. Vogel, assistant curator of civil and mechanical engineering, made several visits to museums and other institutions in New York, Pennsylvania, New Jersey, and Delaware in connection with the planned Smithsonian Hall of Engineering. He examined extensive collections of photographs of bridges, tunnels, and other structural works and investigated various historic examples of refrigera-

tion, farm machinery, elevators, and mills, with a view to the possible acquisition of materials for exhibit in new Smithsonian halls.

Primarily to study models of ships, Howard I. Chapelle, curator of transportation, visited various institutions and individuals in New England, New York, and Virginia. He made arrangements for photographing ships and investigating some builder's models. Of particular value was a visit to the Mariners' Museum at Warwick, Va., where plans are available for several ships built in the late 18th century. Mr. Chapelle's most extensive trip took him to Rome, Paris, and London between April 3 and 18, 1959. In Rome he attended the International Fishing Boat Congress and delivered a paper on hull form. He inspected fishing fleets and shipyards near Rome and also saw models of fishing boats built around 100 B.C. By visiting museums in Paris and London, Mr. Chapelle acquired some very useful information in reference to details of the planned Smithsonian Transportation Hall.

Kenneth M. Perry, associate curator of transportation, made several trips through the Eastern States to acquire models of ships and to examine other models that are being built for the Smithsonian Institution. His visits took him to many museums and shipyards. At the Mariners' Museum at Warwick, Va., Mr. Perry examined a card file of prints and paintings in the collection and recorded those pertaining to clipper ships, pilot boats, and Hudson River steamers with their descriptions.

John H. White, assistant curator of transportation, traveled to museums and other institutions in the eastern United States to acquaint himself with materials pertaining to land transportation. He discussed problems of model making with staff members of various institutions, with particular emphasis on various railroad and street railway collections.

In July 1958 E. C. Kendall, associate curator of agriculture and wood products, spent a few days in New York visiting museums and examining exhibits especially relating to forestry and agriculture. A valuable trip was made to Waynesboro, Pa., on December 4, 1958, to examine the 1877 steam engine owned by the Frick Co., of particular interest since practically all the farm steam engines now available date from the early 1900's. Mr. Kendall also accompanied Mr. Vogel on a trip to the vicinity of Wilmington, Del., on March 24, 1959. At Chadds Ford they visited an old mill now owned by Andrew Wyeth and examined the equipment and machinery. The mill dates from 1762 and was enlarged in the late 18th century by adding another story; it was in operation until 1950. Some machinery of the type in this mill would be useful in the new Agriculture Hall to illustrate early processes relating to flour milling. Between March 27 and

April 10, 1959, Mr. Kendall made a western trip to examine certain pieces of farm machinery. In Detroit he visited the Henry Ford Museum, which has a large collection of machinery including an early mowing or reaping machine made by Enoch Ambler. In Omaha he was much impressed by the Joslyn Art Museum, where he saw good examples of ingenuity in producing effective exhibits at relatively low cost. In California he visited the Caterpillar Tractor Co. near San Francisco and the Holt Brothers in Stockton, examining machinery of potential use in Smithsonian exhibits.

With the intention of examining and perhaps acquiring examples of electrical equipment for the Smithsonian Institution, W. James King, acting curator of electricity, made several field trips. In July 1958 he visited Cornell University to study Anthony's dynamo and a Westinghouse alternator of the late 1880's. In Pittsfield, Mass., he visited the General Electric Co. to examine William Stanley's papers in the Stanley Library and to see the Stanley transformer at the Crane Museum, and at Housatonic, Mass., the site of Stanley's pioneer a.c. power installation. In September Mr. King discussed the new Hall of Electricity with several officials of the American Telephone & Telegraph Co. Visits to the General Electric Research Laboratory, the Chicago Museum of Science and Industry, and the Westinghouse Electric Co. in Pittsburgh, Pa., were productive of ideas for new exhibits for the Smithsonian Institution. Between February 2 and 8, 1959, Mr. King made a tour of various institutions in New England and New York to gain information regarding equipment in connection with the history of radio.

George B. Griffenhagen, curator of medical sciences, made several field trips to museums and pharmaceutical houses throughout the Eastern States, traveling to Chicago, Missouri, and Wisconsin. He investigated several health museums to obtain ideas that might be useful in planning details of new exhibits for the Museum of History and Technology. Mr. Griffenhagen's most extended trip took him to England, Spain, Italy, and Belgium, between August 14 and September 16, 1958. The primary purpose of the trip was to attend the 17th general assembly of the International Pharmaceutical Federation, held in Brussels. Included was an all-day meeting of the World Union of Pharmaceutical Historical Societies, during which Mr. Griffenhagen presented a paper on "The Equipment of the Early American Pharmacy." He also visited the Brussels Universal Exhibition. In Spain, and also in Italy, he saw some outstanding collections of pharmaceutical antiquities and apothecary shop and alchemical laboratory restorations.

Between November 17 and 21, 1958, Dr. John B. Blake, associate curator of medical sciences, studied the clinical amphitheater at the

Pennsylvania Hospital in Philadelphia and the Fry collection of medical prints in New Haven and examined the outstanding microscope collection of Dr. George S. M. Cowan in New York. He also made trips to institutions and individuals in the Eastern States to study problems of historical importance in the medical field.

Dr. Philip W. Bishop, head curator of arts and manufactures, visited Chicago between October 26 and 29, 1958, to inspect the Whiting refinery and meet its officials, primarily to discuss the origins of thermal cracking of crude petroleum. He also visited the Museum of Science and Industry to see and measure the Nasmyth steam hammer. In November 1958 he visited the Ethyl Corp. and the Esso Standard Oil Co. in New York to discuss matters of mutual interest pertaining to the Hall of Petroleum of the Museum of History and Technology. Between January 19 and 23, 1959, he visited several institutions in southern California, primarily to inspect nuclear research activities and to examine data on various geological formations as an aid to planning some of the new halls for the Smithsonian Institution. In New York in April and June he inspected a model of a deep-sea drilling barge and examined details of a fluid catalytic cracking model.

Between September 28 and October 4, 1958, Miss Grace L. Rogers, acting curator of textiles, visited New Haven, Boston, and other areas in New England. She made an extensive study of an original model of the Whitney cotton gin in the collections of the New Haven Colony Historical Society. At Jewett City, Conn., she examined the old Jacquard loom that was being assembled for the renovated Textile Hall of the Smithsonian Institution. The Old Slater Mill Museum in Pawtucket, R.I., provided a valuable opportunity to study a collection of old textile machinery and noted exhibition techniques.

Paul V. Gardner, acting curator of ceramics and glass, made several trips during the year to Norwood, Mass., to select, list, and pack various pieces of rare glass presented to the Smithsonian Institution by Mrs. Clara W. Berwick. Between August 20 and 23, 1958, he visited the Corning Museum of Glass at Corning, N.Y., where he studied many samples of different glass objects. Here it was possible to run ultraviolet light tests on a number of glass objects from the Smithsonian collections to determine their origin and age. From September 8 to 15, 1958, Mr. Gardner visited New York and various points in New England to talk with collectors and dealers in the interest of obtaining additional ceramics and glass collections for the Smithsonian.

Between September 25 and 30, 1958, Jacob Kainen, curator of graphic arts, visited Kansas City to study the engravings of Hendrick Golzius (1558-1617) in pursuance of a research project, particu-

larly in the Print Department of the William Rockhill Nelson Gallery of Art. He visited New York between March 22 and 28, 1959, to check data for his study of John Baptist Jackson, to study the work of Hendrick Golzius, and to select prints for possible purchase for the new Museum of History and Technology. Mr. Kainen visited the New York Public Library, the Frick Art Reference Library, and the Metropolitan Museum of Art. Between May 20 and 24, 1959, he made a trip to Sarasota, Fla., to gather further background data in connection with his research project on Golzius. An extended visit to the Ringling Museum permitted Mr. Kainen to study the largest collection of baroque art in this country and to note its international influences.

Alexander J. Wedderburn, associate curator of photography, visited New York City between May 27 and 29, 1959, to discuss material for exhibit in the Museum of History and Technology with a number of manufacturers and distributors.

Fuller O. Griffith, assistant curator of graphic arts, spent 3 days in New York in November 1958, carrying out research for his catalog of lithographs of the American artist Childe Hassam (1859-1935). He visited the Knoedler, Kennedy, and Weyhe galleries, where he examined numerous prints by Hassam, as well as the Grand Central Art Galleries, the New York Historical Society, the Pierpont Morgan Library, and the New York Public Library, where there is a large body of Hassam's lithographs.

Rudolph G. Morris, museum aide, division of graphic arts, visited the Rochester, N.Y., Museum of Arts and Sciences in January 1959 to discuss with staff members the role of photography and the Museum's audiovisual program. Extending his visit to Holyoke, Mass., he made an extensive tour of inspection of the facilities of the Technifax Corp. and discussed research facilities with members of the staff.

The head curator of civil history, Dr. Anthony N. B. Garvan, made several trips to institutions and other organizations in the eastern half of the country in connection with his historical studies. In July he visited the Marine Historical Association in Mystic, Conn., where he discussed with staff members the possibility of acquiring objects relating to marine industry for exhibit in the Growth of America Hall. In October he went to St. Louis, Mo., where he spent some time with the National Park Service, selecting structural and decorative iron from the vast accumulation preserved by that Service. At Williamsburg, Va., Dr. Garvan visited the Information Center in February 1959, and examined new exhibits and material of possible value to the Smithsonian Institution. He viewed a superb series of plaster models of houses showing their outline and linking them with horizontal photographs and labels. He also examined a complete archeological

site made of a new plastic material so realistic and so colored to resemble earth, brick, stone, etc., that the visitor feels that the actual site has been transported into the museum. At Jamestown Dr. Garvan examined a variety of objects recovered from the area in the anticipation that some of these may be used in the Smithsonian's hall demonstrating the growth of the United States.

In August 1958 Dr. Wilcomb E. Washburn, curator of political history, spoke at a dinner meeting of the Eastern Shore of Virginia Historical Society on the personalities of Governor Sir William Berkeley and rebel Nathaniel Bacon. Subsequently he examined several historic sites in the area, including St. George's Church, where archeological work is taking place, and Hungars Church. In November 1959 he went to Princeton, N.J., to participate in a conference of the Institute of Early American History and Culture of Williamsburg, Va., following which he did some research in the manuscript collections of the University Library. In Baltimore he examined the observation platform that the Baltimore & Ohio Railroad expects to donate to the Smithsonian Institution for use in a political history exhibit.

Mrs. Margaret B. Klapthor, associate curator of political history, traveled to New York in January 1959 to pursue her research on matters pertaining to the First Ladies Hall. She selected samples of fabrics and discussed in some detail two mannequins to be used.

Charles G. Dorman, assistant curator of political history, visited Dover and Wilmington, Del., in March 1959 to study 18-century tax lists. He located hitherto unknown midcentury cabinetmakers and followed the movements of others who moved about the colony after their apprenticeships had been served. Mr. Dorman also spoke on the subject of "Philadelphia Presidential Mansion" at a meeting of the Chester County Historical Society, West Chester, Pa. Between May 19 and 24, 1959, he visited several towns in New England to study museum design and exhibits installation. He also gave a talk before the Quincy Historical Society of Quincy, Mass., on "The Adams Family in Washington, 1800-1847."

To examine collections offered the Smithsonian Institution by various individuals, C. Malcolm Watkins, acting curator of cultural history, made several trips to points in the Eastern States. At Wilmington, Del., in December 1958, he examined a loghouse offered to the Institution for exhibit purposes and discussed ways and means of dismantling it and shipping it to Washington.

Rodris C. Roth, assistant curator of cultural history, visited Philadelphia in September 1958 for research at the American Swedish Historical Foundation and Museum pertaining to an exhibit on Scandinavian backgrounds planned for the Hall of Everyday Life in

Early America in the new Museum of History and Technology. In connection with planning for this hall, she visited the Winterthur Museum in Delaware in December 1958 and again in June 1959. At the Baltimore Museum of Arts, Miss Roth studied an imaginative display entitled "Age of Elegance, the Rococo and Its Effect," consisting of an assemblage of fine and decorative arts of the 18th century grouped by country of origin.

George T. Turner, acting curator of philately and postal history, and Francis J. McCall, associate curator of that division, attended the American Stamp Dealers' Show in New York in November 1958. They displayed a special Smithsonian exhibit, and Mr. Turner gave a talk on the history of the National Postage Stamp collection and its development under the preceding curators. During the first 10 days of 1959 Mr. Turner visited several cities in California to meet numerous philatelists, to inform them of the material needed in the exhibits planned for a new hall, and to tell them something of the stamps missing in the National collection. He spoke before a meeting of the Philatelic Research Society on the "Activities of the Smithsonian's Division of Philately and Postal History."

On two occasions Francis J. McCall visited New York City to discuss with several philatelists material of potential interest to the Museum of History and Technology. At the New York Historical Society, the Philatelic Society, and the New York Public Library he supplemented previous studies and strengthened contacts with staff members. Between October 31 and November 2, 1958, he attended the American Philatelic Congress in New York. From March 15 to 20, 1959, he visited Boston and Cambridge, Mass., to discuss with philatelists matters of mutual interest and to study documents at various libraries.

Dr. Vladimir Clain-Stefanelli, curator of numismatics, made several trips to New York, Philadelphia, St. Louis, and cities in Massachusetts during the year to select material missing from the Smithsonian library. On September 16, 1958, he gave an illustrated address to the Philadelphia Coin Club concerning the history of the Smithsonian and of the national coin collections. In October 1958 he spent several days in Worcester, Mass., where he visited the American Antiquarian Society and studied their collections of colonial notes. At the Worcester Numismatic Club he discussed the Smithsonian's modernization program and examined a collection of German Renaissance medals, multiple talers, and ancient Greek coins. In February 1959 he spent several days in New York, principally at the museum of the American Numismatic Society, where he studied posthumous Lysimachus gold and silver coinages struck in various ancient Greek cities.

In Philadelphia, Mrs. Elvira Clain-Stefanelli, assistant curator of numismatics, examined a collection of Mrs. Catherine Bullowa, from which she was able to select for the national collections numerous coins, medals, and tokens in silver, copper, and other metals, representing practically all periods, from the early 13th century to date. In September 1958 she went to New York to study Italian numismatic periodicals at the library of the American Numismatic Society in order to complete a study on modern Italian coin engravers.

From May 14 to 18, 1959, Dr. and Mrs. Clain-Stefanelli went to Albany, Gloversville, and New York, N.Y. In the New York State Museum they had useful discussions with staff members about early trade and examined unusual collections of wampum beads and ceremonial belts. Dr. Albert F. Goodwin, of Gloversville, permitted them to study his very fine collection of foreign medals and decorations.

During the year Mendel L. Peterson, head curator of Armed Forces history, made several trips to Boston, New York, and several other east-coast cities. In Trenton, N.J., at the State Museum Building, he attended an open meeting on the subject of underwater exploration, where he delivered a lecture. The Museum of the Naval Academy at Annapolis, Md., disclosed some material that will be useful to the Smithsonian exhibition series, including, for example, a letter written by John Paul Jones.

Edgar M. Howell, acting curator of military history, made several trips to points in the eastern United States and Canada in connection with material needed by the Smithsonian for exhibit. Between September 8 and 12, 1958, he visited the Canadian War Museum in Ottawa, the Citadel in Quebec City, Fort Henry at Kingston, Ontario, and Fort Niagara, in New York, studying collections and exhibit techniques and photographing specimens. He made especially valuable contacts with curators specializing in the French and Indian War and the War of 1812 periods. Between April 20 and 24, 1959, Mr. Howell visited the Fort Sumter National Monument, the Confederate Museum, and the Charleston Museum in Charleston, S.C., the Museum at Grant Park in Atlanta, Ga., and the Castillo de San Marcos in St. Augustine, Fla., studying collections and observing new exhibit techniques.

Craddock R. Goins, Jr., assistant curator of military history, visited several museums in New York State during the period August 25 to 30, 1958, to study ordnance material, observe special exhibit techniques, and arrange for the acquisition of specimens needed in the Hall of Ordnance, in the Museum of History and Technology. The most comprehensive collections of ordnance material in New York State are part of the Museum of the U.S. Military Academy at

West Point. Here Mr. Goins was particularly interested in the extensive collection of artillery tubes. The library of the Military Academy also includes a considerable quantity of material concerning ordnance boards, which is missing from the Ordnance Department records in the National Archives. In February 1959 he made a short trip to Harpers Ferry, W. Va., to examine records in the custody of the National Park Service pertaining to a study he is preparing on the Hall rifle.

Lucile McCain, assistant registrar, visited museums in London and in Leiden, Holland, between September 17 and October 27, 1958, to examine their registration methods. At the British Museum (both Natural History and Bloomsbury), the Victoria and Albert Museum, and the Rijksmuseum in Leiden Miss McCain learned much from the methods in use, particularly as they refer to customs matters and to plans for reviewing permanent files after 25 years.

Members of the staff of the office of exhibits traveled during the year in order to examine exhibits techniques used by various museums, with a view to their application to the new halls in the Museum of History and Technology and the Museum of Natural History.

John E. Anglim, chief exhibits specialist, spent the period April 24 to June 20, 1958, in Europe, where he visited 16 cities in 10 countries and inspected about 70 museums and attended the World's Fair in Brussels. His general impression of European museums is that nearly everywhere they are attempting to bring their exhibitions up to higher standards.

R. O. Hower, supervisory exhibits specialist, visited New York in November 1958, to examine new exhibition techniques in the American Museum of Natural History and the Metropolitan Museum of Art, where many new techniques are being developed in the exhibits laboratories.

Benjamin Lawless, supervisory exhibits specialist, and Robert Widder, exhibits designer, visited New York between September 16 and 18, 1958, to discuss with specialists various types of illumination for the new exhibits of the Smithsonian Institution. In March 1959 Mr. Lawless visited the new Museum of Military History and Science at the U.S. Military Academy, at West Point, where he examined the extensive modernization that has been completed there. In May 1959, accompanied by James A. Mahoney, exhibits designer, he went to Chicago and Cleveland to examine various types of exhibition cases now being devised or in use.

Between August 19 and 22, 1958, Judith Borgogni, exhibits designer, and Violet Moyer, exhibits worker, went to New York to study exhibit techniques and to discuss trends in the exhibition of costumes and fashions. Among institutions visited were the Museum

of the City of New York, the Metropolitan Museum of Art, and the New York Public Library.

William E. Geoghegan, exhibits technician, with Kenneth Perry, visited Warwick and Richmond, Va., between October 29 and 31, 1958. At the Mariners' Museum in Warwick and at the Confederate Museum in Richmond they worked on models of ships that will be exhibited in the Museum of History and Technology. In November 1958 Mr. Geoghegan went to Providence, R.I., and Essex, Conn., to examine the models of certain historic ships. Work on several such models is progressing as anticipated and it is expected that they will greatly enhance the educational value of the hall being planned by the division of transportation.

Exhibits technician Chris Karras made a field trip in May 1959 that took him to several museums in the eastern half of the country. He was mainly interested in marine biological displays in connection with the new Hall of Oceanic Life that is being planned for the Museum of Natural History.

Mrs. Ann Karras, exhibits designer, visited the Cincinnati Art Museum and the Taft Museum, in Cincinnati, Ohio, in June 1958 to acquire background information for details of the Hall of Musical Instruments of the Museum of History and Technology. Between November 15 and 26, 1958, she visited several museums for the purpose of studying fossil mammal exhibits, in connection with a pending renovation of a hall in our Museum of Natural History. This visit took her to the Chicago Natural History Museum, the University of Nebraska State Museum, the Denver Museum of Natural History, the Peabody Museum of Natural History at Yale, and the American Museum of Natural History.

Between November 17 and 21, 1958, James A. Mahoney, exhibits designer, visited George Eastman House, Eastman Kodak Co., and Bausch & Lomb Co. in Rochester, N.Y., for technical data needed in the Hall of Photographic History, in the Museum of History and Technology. He obtained much valuable information, and got a general view of present methods of displaying photographic and historical topics.

William Pennock, exhibits designer, went to New York in the company of Dr. Clain-Stefanelli between August 7 and 9, 1958, to examine various exhibit methods, color and lighting techniques, case designs, architecture, and manufacturing processes pertaining to numismatic displays.

John C. Widener, exhibits specialist, attended sessions of the National Plastics Exposition held in Chicago from November 17 to 21, 1958. He discussed the utilizations of various plastics with specialists who attended the exposition and visited several companies in order to

investigate their products and techniques, in connection with the use of plastics in exhibit construction at the Smithsonian Institution.

EXHIBITIONS

The progressive modernization of the exhibition halls of the Smithsonian Institution was carried forward. The program has now completed 5 years. Construction bids were received in May 1959 for the second North American Archeology Hall, and in June 1959 for the halls that will be devoted to the geological and fossil record of the age of mammals; medical and pharmaceutical history; and the history of money or numismatics.

The formal opening of the renovated Graphic Arts Hall in the connecting range of the Smithsonian Institution Building was held on the evening of July 10, 1958. Prentiss Taylor, president of the Society of Washington Printmakers, was the principal speaker. Hand processes employed to produce etchings, wood engravings, lithographs, and silk-screen prints are displayed in this hall. The history of printing from the invention of the alphabet to the commercial production of the printed book is illustrated by an original woodcut for a page of a very old Chinese block book, a reproduction of ancient Korean movable type, and a page from the Gutenberg Bible of about 1454.

The newly modernized Hall of Gems and Minerals in the Natural History Building was dedicated by Secretary Leonard Carmichael on the evening of July 31, 1958. Mrs. W. F. Foshag, wife of the late head curator of the department of geology, was invited to cut the ribbon at the formal opening. Exhibits in this hall include the most extensive collection of gems on display in this country, and a large and representative sampling of specimens from the national mineral collection, which is regarded as the world's finest. Nearly every variety of gem is represented. Included in this display are: A 316-carat star sapphire; an 18.3-carat canary-yellow diamond; a 66-carat alexandrite; and a 310-carat peridot. Among the historic items shown is a set of pearls consisting of a necklace, choker, and earrings given by the Imam of Muscat to the U.S. Government; the original gold nugget responsible for the initiation of the California gold rush which was discovered at Sutter's Mill in 1848 by James Marshall; and the world's largest flawless quartz crystal ball, a sphere almost 13 inches in diameter and weighing 106¾ pounds. The Hope diamond, a gift of Harry Winston, world-famous gem merchant of New York, is spotlighted against a dark-red velvet in a centrally located, specially designed case. In the mineral section of this hall are shown examples of all the principal kinds of minerals, arranged in accord-

ance with a chemical classification, and selected and lighted to make a colorful display of their natural beauty. A fine large specimen of smithsonite, a carbonate of zinc, named for its discoverer James Smithson, whose bequest founded the Smithsonian Institution, is exhibited in this hall. The spectacular display of fluorescent minerals on a revolving stand has attracted considerable visitor interest.

The room designed solely for the display of the Maude Monell Vetlesen collection of Chinese jade carvings of the 16th to 19th centuries was opened to the public on the evening of December 11, 1958, in ceremonies featuring addresses by the Vice President of the United States and Regent of the Smithsonian Institution Richard M. Nixon, Edmund C. Monell, the Honorable Wiley T. Buchanan, Jr., Chief of Protocol of the United States, and Dr. Leonard Carmichael, Secretary of the Smithsonian Institution. These pieces of exquisitely carved jade include an apple-green chrysanthemum dish of nearly 11½ inches in diameter, a massive white imperial altar incense burner and cover of classic design, a pair of deep spinach-green altar boxes in the shape of the divine tortoise, and two imperial scepters, made of gold filigree and each inset with three large carved jade plaques.

The basic contract construction of the Hall of Fossil Fishes and Primitive Tetrapods, as well as the Hall of Fossil Invertebrates and Plants, was completed in May 1959. Shortly thereafter the exhibits staff placed in their respective cases the giant fish *Xiphactinus* and the slab displaying the skeleton of the Triassic amphibian *Eupelor fraasi*. Materials for other display units have been prepared for installation. In addition to the materials prepared by the museum's exhibit staff, two habitat groups, depicting Cretaceous and Ordovician life associations, were completed and two additional groups were being prepared with the help of George Marchand of Ann Arbor, Mich.

Preparators in the paleontology laboratory commenced the assembly of mammalian skeletons for the Age of Mammals Hall. Skeletons of the Eocene horse *Orohippus*, the Oligocene *Mesohippus*, and the Miocene *Parahippus* are in various stages of completion.

The unveiling of the Fénykövi elephant on the evening of March 6, 1959, was witnessed by a large number of invited guests following a lecture in the auditorium of the Natural History Building by the donor. This record specimen of African bush elephant, standing 13 feet 2 inches at the shoulder, is the largest land mammal ever to be placed on display. Josef J. Fénykövi, Hungarian-born engineer and big-game hunter who tracked down and shot this elephant in the largely unexplored Cuando River region of southeastern Angola on November 13, 1955, and who presented the specimen to the Smithsonian Institution, came to Washington with his wife from Madrid to participate in the

ceremonies. This elephant has been placed in the center of the rotunda of the Natural History Building.

The preparation and installation of the habitat groups and topical displays were nearing completion at the end of the fiscal year in the two halls featuring the World of Mammals, following the contract construction of the exhibit fixtures in June 1958. Nearly all the topical units have been installed and much of the work on the habitat groups is completed. Staff zoologists under the chairmanship of Dr. Herbert Friedmann, head curator of zoology, continued to develop plans for the Hall of Oceanic Life.

Associate Curator Clifford Evans, in cooperation with John C. Ewers, Assistant Director of the Museum of History and Technology, Howard Cline of the Hispanic Foundation of the Library of Congress, and John Corbett of the National Park Service, prepared the scripts and supervised the installation of an exhibit, "Anthropology and the Nation's Capital," which was shown in the foyer of the Natural History Building during November and December 1958 coincident with the annual meetings in Washington of the American Anthropological Association and the American Association for the Advancement of Science.

Three types of prehistoric surgery, assembled by Dr. T. Dale Stewart, curator of physical anthropology, were shown at the January 1959 meeting of the Regents of the Smithsonian Institution: (1) Amputation of the right arm in the Shanidar I Neanderthal skeleton from Iraq (45,000 years old); (2) cranial trephining from Peru; and (3) filed teeth from the Mississippi Valley.

The panels of photographs at the south end of the hall devoted to Highlights of Latin American Archeology were removed and a large, full-size plaster cast of a colossal stone head of the Olmec culture was installed in February 1959. This cast of San Lorenzo Monument No. 1 from southern Veracruz was delivered in 31 sections and was assembled by Paul Willis of the cabinet shop, with the artwork and final painting performed by A. Joseph Andrews, chief exhibits specialist of the department of anthropology. Three carved jade figures from La Venta in Tabasco, Mexico, as well as other Olmec jade objects such as beads, ceremonial axes, pendants, and ear ornaments, were installed in June 1959 in an exhibit adjacent to the head. This exhibit also illustrates aboriginal methods of working jade by drilling, sawing, pecking, and polishing. The Andean arts and crafts exhibit was renovated in December 1958 and a few objects were withdrawn to permit the installation of a gold Chimú mask from Peru.

At the close of the fiscal year construction of the exhibit fixtures for Hall 21, which will feature the archeology of the southwestern United States, the Pacific coast and Columbia River Valley, and Arctic

America, was well advanced toward completion. A series of general displays, such as native mines and quarries, Indian stoneworking methods and products, Euroamerican trade items from Indian sites, native smoking devices, and the diffusion of tobacco are planned for topical purposes.

The Third Biennial Creative Crafts Exhibition was shown from August 27 to September 26, 1958, in the foyer of the Natural History Building. This was organized and installed by local craft organizations and sponsored by the division of ceramics and glass. Contemporary examples of ceramics, textiles, jewelry, and woodworking were displayed, and daily demonstrations of pottery making, weaving, and other craftwork conducted.

A ceremony of acceptance was held on the afternoon of December 11, 1958, to open the E. Stanley Wires collection of decorative tiles in the specially reconditioned room in the foyer of the National History Building. New acquisitions of glass from Mrs. Clara W. Berwick and of Castleford porcelain from Mrs. George Hewitt Myers were also put on exhibition, and two appropriate cases were built to house a collection of paperweights lent by Mrs. Florence Bushee.

Historic Dutch and Rhenish pottery and stoneware now displayed in a large alcove at the west end of the Cultural History Hall in the Natural History Building were formally accepted by Secretary Leonard Carmichael as a gift from the Honorable Wiley T. Buchanan, Jr., Chief of Protocol of the United States, and Mrs. Buchanan on the afternoon of January 5, 1959. All these examples of ceramics were excavated at sites in the Netherlands and assembled by P. Weers of Vooburg. The exhibit illustrates household ceramics from the Roman and Merovingian periods to the beginning of the 19th century, and provides a basis for an understanding of the materials exported to America during the period of early settlement as well as its influence on the workmanship of American potters of the 17th century.

The renovated textile exhibit located in the main south hall of the Arts and Industries Building was formally opened to the public on the evening of January 20, 1959, by A. E. Wullschlegler and Secretary Carmichael. In this hall the exhibits trace the history of the fibers and fabrics used by man in the context of the implements and machines that produced them, with the emphasis placed on the technological developments from colonial times through the ensuing years. The Eli Whitney cotton gin and the Samuel Slater cotton machinery from the Pawtucket Mill of 1790, both unique examples of the work of these skilled mechanics, are supplemented by many other historic devices. Among these are a well-preserved Jacquard loom from Lyons, France, presented by Mr. Wullschlegler, of New

York. No more than 4 or 5 inches of fabric could be woven on this loom in a day. Fabrics from ancient Egypt, Colonial America, and contemporary hand- and power-woven fabrics show the development of the art of weaving. Another featured exhibit is an early 18th-century Don Quixote tapestry presented by Mrs. Kermit Roosevelt.

Contract construction work on the fixtures in the south hall gallery of the Arts and Industries Building for display of the dyeing and printing of fabrics, needlework and lace crafts, and the development of the sewing machine was nearing completion in June 1959. Renovation of the southeast range of the Arts and Industries Building, which will be utilized for the display of farm machinery and other agricultural implements, was completed in April 1959 by the construction contractor. These exhibits will trace the growth of labor-saving farm machines in America, with particular emphasis on the 19th century, during which various types of machinery were invented or perfected for efficient planting, cultivating, and harvesting of the Nation's rapidly expanding farm acreage.

With the cooperation of a number of leading concerns in the petroleum industry, plans have been developed for a small hall to illustrate the history of this important industry.

During March and April 1959 the Atomic Energy Commission's traveling exhibition "You and the Atom" was presented to the public in the rotunda of the Arts and Industries Building.

On June 24, 1959, a construction contract was awarded for the renovation of the east gallery of the Arts and Industries Building in which will be installed a series of new display units interpreting the history of medicine and pharmacy. These display units will be moved to the Museum of History and Technology where they will comprise portions of the more comprehensive exhibits in the fields of medical, dental, and pharmaceutical history. The most important new exhibits installed in the division of medical sciences during the year were the two cases prepared and contributed by the National Foundation for Infantile Paralysis, which illustrate the discovery and development of the Salk poliomyelitis vaccine.

An exhibit of "World Ebonies," selected from the Rudolph Block collection of walking sticks, was installed in the corridor through the hall of wood products; and four exhibit units displaying American oaks, other important American hardwoods, fruitwoods, and foreign cabinet woods are being renovated.

A temporary exhibit was prepared to commemorate the 100th anniversary of the birth of William Stanley. He was responsible for the design of the first practical electrical transformer and for the first demonstration of an a.c. power distribution system in the

United States. The use of transformers made it possible to send electrical power over great distances, instead of being limited to a mile or so from the generating station.

Additions to the horological exhibits included a large operating model of the Hamilton electric clock, constructed on a scale of 8 to 1, and a group of recently cleaned and restored Japanese clocks. During the annual meeting of the National Association of Watch and Clock Collectors in May 1959, a number of New England watches were placed on display.

The completely renovated 1893 Duryea automobile was returned to the exhibition series and the Cornell-Liberty Mutual survival car was placed on temporary exhibition.

A special exhibit commemorating the 150th anniversary of the birth of Abraham Lincoln was opened in the west hall of the Arts and Industries Building on February 11, 1959. Selected items from the Museum's collection of Lincoln memorabilia and a life-size figure on which is displayed the office suit worn by President Lincoln on the morning of his assassination comprise the essential elements of this exhibit. Included are many of the items that have recently been donated to the Institution by Lincoln Isham, of Dorset, Vt., great-grandson of President Lincoln. At the same time the division of philately prepared a special exhibit, "Lincoln on Stamps," including free franked covers of Mrs. Lincoln lent through the assistance of Mrs. Morton Dean Joyce of New York, and the division of numismatics arranged groups of Lincoln medals to portray Lincoln's life and impact on history. The division of numismatics also prepared a large exhibit of U.S. commemorative coins, presidential medals, and American medallie art for the first Ibero-American Numismatic Exhibition in Barcelona, Spain, which opened November 24, 1958.

The department of Armed Forces history presented two special exhibitions in the rotunda of the Arts and Industries Building during the year. From July through September 1958 a special showing of the Tole paintings of Mrs. Irving Olds and naval prints from the collection of Mr. Olds was displayed under the joint sponsorship of the U.S. Marine Corps and the division of naval history. A special exhibition featuring the submarines *Nautilus* and *Holland* was set up during May 1959.

During the year the appearance of the uniforms exhibited on the west gallery of the Arts and Industries Building was materially enhanced by placing them on adjustable mannequins.

DOCENT SERVICE

In January 1959 the general direction of the educational program of volunteer docent guide service, conducted with the cooperative as-

sistance of the Junior League of Washington, was transferred to the Smithsonian Museum Service. This program had been under the direction of Frank M. Setzler, head curator of anthropology, since its inception in 1955. This transfer was made in accord with the purposes for which the Museum Service was established. The program continued under the supervision of G. Carroll Lindsay, acting curator of the Smithsonian Museum Service, working with Mrs. Peter Macdonald, volunteer chairman of the Smithsonian Docent Committee of the Junior League of Washington. After serving for 2 years as chairman of this committee, Mrs. Macdonald submitted her resignation at the conclusion of the tours season. She was succeeded as chairman by Mrs. C. Clarke Gearhart, formerly cochairman of the docent committee. Mrs. Dean Cowie will serve as co-chairman of the committee with Mrs. Gearhart.

During the 6-month season beginning in October 1958, 398 tours were conducted, in which 11,996 children were escorted through the 3 exhibit halls included in the docent program—the American Indian Hall, the Hall of Power Machinery, and the Hall of Everyday Life in Early America. This represented an increase of nearly 50 percent in the total number of children participating in this program over the previous year.

In addition to Mrs. Macdonald and her cochairman, Mrs. Gearhart, the following members of the Junior League of Washington participated in the docent work: Mrs. George Armstrong, Mrs. Harrison Brand III, Mrs. Dean Cowie, Mrs. Walter Edwards, Mrs. William Graves, Mrs. H. F. Gregory, Miss Mary Harbert, Mrs. Edward Lamont, Mrs. Ralph W. Lee III, Mrs. John Manfuso, Jr., Miss Grace C. Marshall, Mrs. William McClure, Jr., Mrs. Robert McCormick, Mrs. John A. Medaris, Mrs. William Minshall, Mrs. Minot Mulligan, Mrs. George Pendleton, Mrs. John Schoenfeld, Mrs. W. James Sears, Mrs. William D. Sloan, Jr., Mrs. Walter Slowinski, Mrs. James H. Stallings, Mrs. E. Tillman Stirling, Mrs. G. G. Thomas, Mrs. David Toll, Mrs. Richard Wallis, Mrs. Marc A. White, and Mrs. George A. Wyeth, Jr.

In the coming season, the docent service will be extended to two more exhibit areas—the Hall of Gems and Minerals and the Hall of Textiles.

BUILDINGS AND EQUIPMENT

Senator Clinton P. Anderson, Regent of the Smithsonian Institution and chairman of the Joint Congressional Committee on Construction of a Building for a Museum of History and Technology, turned the first shovelful of earth on August 22, 1958, and excavation for the foundations was commenced immediately. At the close of the fiscal year the excavation and driving piles had been accomplished. Work-

ing drawings and specifications for the building were completed by the contract architects, McKim, Mead & White, and reviewed by the Smithsonian Institution and the General Services Administration. The construction of the superstructure was advertised for bids on June 23, 1959.

Working drawings for the construction of additions to the Natural History Building were completed by the contract architects, Mills, Petticord & Mills, and were reviewed in detail by the staff of the Smithsonian Institution. Thus the architectural planning for these wings, which are urgently required to house the increasing scientific collections and to provide efficient working facilities for the staff, has been accomplished. The Congress recognized the immediate need for these additions when it appropriated the funds for the architectural services to prepare the working drawings. The Smithsonian Institution is now prepared to contract for the construction of the additions when funds are appropriated for the purpose.

John E. Cudd, architect of the Public Buildings Service assigned to the Smithsonian Institution, continued to advise on both building projects, assisting in the transmittal of requirements to the architects and in the review of the drawings and specifications. Many individuals and sections of the Public Buildings Service contributed counsel and advice.

The contract work for replacement of the roof covering on the Natural History Building, the first phase of which was started in the fiscal year of 1957, has been completed. This project included the removal of the skylight glass, the installation of sheathing and metal covering, and the installation of fluorescent lighting to provide uniform illumination in the three large halls.

The floors of the auditorium in the Natural History Building have been re-covered to minimize the hazards of the sharply inclined aisles as well as to provide a more noiseless walking surface.

A revised electrical system has been installed to serve the Arts and Industries, Smithsonian, and Freer Buildings. This project required the construction of two additional transformer vaults, the installation of two transformers, and the extensive revision of the electrical service in order to provide sufficient electrical capacity to serve the constantly increasing needs of the Institution.

The east entrance of the Arts and Industries Building has been remodeled to permit installation of a heavy-duty hydraulic elevator for use in the handling of large and heavy objects from truck height to floor level. The combination of this elevator with a full-height rollup-type door will be especially useful during the transfer of museum objects from the Arts and Industries Building to the Museum of History and Technology on its completion. Many former hazards oc-

curing during handling of heavy objects at this entrance have been eliminated.

All exterior surfaces of window sash and frames of the Natural History Building were painted and glass replaced where necessary. During the year many offices and workrooms have been renovated, including those of the registrar, division of political history, and the library.

CHANGES IN ORGANIZATION AND STAFF

Dr. A. C. Smith was appointed Director of the Museum of Natural History effective August 28, 1958, following transfer from the National Science Foundation.

John C. Ewers was promoted to Assistant Director of the Museum of History and Technology on November 29, 1958.

Dr. Ralph S. Solecki, associate curator of archeology, resigned on June 30, 1959, to accept an associate professorship in anthropology at Columbia University. In the division of ethnology of the department of anthropology, Dr. Gordon D. Gibson accepted an appointment as associate curator on July 30, 1958, and Dr. Eugene Knez as associate curator on April 30, 1959.

Dr. Peter P. Vaughn, associate curator of vertebrate paleontology, resigned on January 15, 1959, to accept an appointment tendered by the University of California at Los Angeles. This vacancy was filled by Dr. Nicholas Hotton III, who reported for duty June 1, 1959.

George B. Griffenhagen, curator of medical sciences since December 8, 1952, resigned on June 27, 1959, to accept the position of director of communications for the American Pharmaceutical Association.

The curatorial vacancy in the division of philately and postal history was filled by the appointment of George T. Turner on July 7, 1958.

Dr. Philip K. Lundeberg was appointed as associate curator, division of naval history, effective June 10, 1959. Dr. Lundeberg has been serving as consultant in the department of Armed Forces history since January 19, 1959. Peter C. Welsh accepted an appointment as associate curator in the department of civil history and reported for duty June 15, 1959.

John D. Shortridge was appointed, effective July 28, 1958, associate curator of musical instruments in the division of cultural history, and G. Carroll Lindsay, associate curator of cultural history, was transferred to the Smithsonian Museum Service.

William L. Brown, zoological exhibits specialist and chief taxidermist, retired on June 30, 1959, after 51 years 3 months of service in the taxidermy shop. Mr. Brown was responsible for the modeling and preparing for display of the major portion of the mammals ex-

hibited in the Natural History Building. He was recognized by co-workers as one of the foremost skilled artisans and modelers of naturally posed mammals and gained an enviable reputation for the excellence of his work.

Dr. Egbert H. Walker, associate curator in the division of phanerogams, retired on June 30, 1959. Dr. Walker, who was appointed to the Smithsonian staff on July 2, 1928, has specialized in the taxonomy and pertinent bibliography of eastern Asiatic flowering plants. He plans to continue, under the aegis of the American Institute of Biological Sciences, his preparation of a supplement to Merrill and Walker's "Bibliography of Eastern Asiatic Botany" (1938).

Clarence R. Shoemaker, who was appointed research associate following his retirement on March 30, 1944, as assistant curator of marine invertebrates after having served more than 34 years as an employee of the Institution, died on December 28, 1958, in Washington, D.C. Mr. Shoemaker was a recognized amphipod specialist.

Dr. Frederick L. Lewton, research associate who retired on June 30, 1946, as curator of arts and industries after 44 years of service in the U.S. National Museum, died on February 21, 1959, at Winter Park, Fla.

Dr. John B. Reeside, Jr., research associate in invertebrate paleontology since June 19, 1944, died in Hyattsville, Md., on July 2, 1958. Dr. Reeside has also served for 17 years as chief of the paleontology and stratigraphy branch of the U.S. Geological Survey.

Paul A. Straub, research associate in numismatics since July 6, 1955, died at Summit, N.J., on December 9, 1958. Mr. Straub donated to the division of numismatics over 5,000 gold and silver coins representing a span of 400 years. Because of the many outstanding rarities included in the collection, these coins as a whole are priceless and, in addition, enable the Smithsonian Institution to display to its visitors the largest exhibit of gold coins in the world.

Respectfully submitted,

REMINGTON KELLOGG, *Director.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the Bureau of American Ethnology

SIR: I have the honor to submit the following report on the field researches, officework, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1959, conducted in accordance with the act of Congress of April 10, 1928, as amended August 22, 1949, which directs the Bureau "to continue independently or in cooperation anthropological researches among the American Indians and the natives of lands under the jurisdiction or protection of the United States and the excavation and preservation of archeologic remains."

SYSTEMATIC RESEARCHES

(Prepared from data submitted by staff members)

Dr. Frank H. H. Roberts, Jr., Director of the Bureau, devoted a portion of the fiscal year to office duties and the general supervision of the activities of the Bureau and the River Basin Surveys. In September he went to the Mesa Verde National Park in southwestern Colorado as a consultant to the Research Committee of the National Geographic Society. While there he visited a number of ruins that are to be excavated to obtain new information on the aboriginal people of the region and also to provide additional exhibit areas for visitors to the park. As a result of the conferences on the Mesa Verde, the National Geographic Society made a grant to the National Park Service to assist in the excavation program on Wetherill Mesa. It is contemplated that the digging will continue over approximately six field seasons. Following the sessions on the mesa, Dr. Roberts spent a day at Hovenweep National Monument on the Colorado-Utah line north of the McElmo Canyon area where the late Dr. J. Walter Fewkes, a former Chief of the Bureau, carried on investigations some 50 years ago. Judging from Dr. Fewkes's report and the condition of the area today, there has been little change since he first described the towers for which the area is famous.

After his return to Washington, D.C., Dr. Roberts went late in September to Athens, Ga., and visited a number of projects in other parts of Georgia and South Carolina where salvage operations were underway, and participated in discussions relative to continuing work

in the area. During the early part of November he went to Austin, Tex., where he attended the Second International Congress of Historians which was being held at the University of Texas. He served as one of the commentators at the session on Pre-Hispanic peoples in the southwestern United States and northern Mexico. Following his return to Washington he took part in the sessions of the American Anthropological Association, and toward the end of the month went to Lincoln, Nebr., to discuss various problems in Plains archeology with members of the Missouri Basin project staff and to attend the sessions of the Annual Plains Conference for Archeology. During December Dr. Roberts was a member of a panel at one of the sessions of the American Association for the Advancement of Science, where the subject of "Anthropology in the Federal Service" was presented.

In January Dr. Roberts attended the meetings of the Committee for the Recovery of Archeological Remains held at the Department of the Interior in Washington, D.C., and presented a summary of the results of the preceding year's activities of the River Basin Surveys. He also took part in discussions pertaining to future plans for the Inter-Agency Archeological Salvage Program. At the end of January he went again to Georgia where he met with representatives from the National Park Service, various State and local institutions, and assisted in the preparation of plans for a salvage program along the Chattahoochee River in Alabama and Georgia. Early in June he went to Colorado where he examined collections pertaining to early inhabitants of the Western Plains area at the Denver Museum of Natural History and in the University Museum at Boulder. Returning to Nebraska he spent several days at the field headquarters and laboratory of the Missouri Basin project at Lincoln where plans were being completed for the summer's investigations in reservoir areas along the Missouri River in South Dakota. From Nebraska Dr. Roberts returned to Washington.

During the fall and winter months Dr. Roberts reviewed several draft manuscripts of technical reports and returned them to their authors with suggestions for correction and revision. In addition, he did the technical editing on a series of six reports on historic sites archeology in the Missouri Basin which will appear as Bulletin 176 of the Bureau of American Ethnology.

Dr. Henry B. Collins, anthropologist, continued his Arctic research and activities. Material was assembled for an analysis of the "Tunnit" legends of the Canadian Eskimos, which describe in some detail the aboriginal inhabitants of the Canadian Arctic. On the basis of recent archeological investigations, particularly those by Dr. Collins in the Hudson Bay region, it appears that the mysterious Tunnits were in fact the prehistoric Dorset Eskimos rather than the

Thule as previously assumed. Also in preparation was an article evaluating recent archeological discoveries in Alaska and northeast Siberia and their bearing on pre-Eskimo and Eskimo culture sequences and relationships in the Bering Strait area.

In December Dr. Collins attended a 2-day conference on polar research held at Hanover, N.H., under the auspices of Dartmouth College and the National Academy of Sciences Committee on Polar Research. The conference discussed the probable future course of polar research in this country and the advisability of establishing a research institute to coordinate and administer scientific research in the Arctic and Antarctic.

In June Dr. Collins went to Burke County, Ga., to examine an old Indian village site near Waynesboro where Dr. Roland Steiner in the 1890's had collected an unusually large number of flint implements, now in the U.S. National Museum. The implements, numbering some 16,000, were of particular interest because most of them were deeply patinated and were types which are now recognized as belonging to the Archaic period; one of the types, an unusual form of asymmetric knife or scraper, was identical with a specialized form characteristic of the prehistoric Dorset culture of the eastern Canadian Arctic. Through the cooperation of Raymond De Laigle, clerk of court of Burke County, and his brothers, Ray and Roy De Laigle, it was possible to locate the site from county records. It was found to be very much as described by Steiner 70 years ago and still prolific in stone artifacts and rejectage. A sizable collection of flint implements and flakes from this and other sites around Waynesboro was brought back for study.

Dr. Collins continued to serve as a member of the research committee of the Arctic Institute of North America, which evaluates applications for research grants, and of the publications committee, which exercises supervision of the Arctic Institute's quarterly journal *Arctic*, its *Technical Papers*, and its series of *Special Publications*. As chairman of the directing committee, Dr. Collins also devoted considerable time to the planning, supervision, and financing of the *Arctic Bibliography*, which is prepared by the Arctic Institute for and with the support of the Department of Defense. This comprehensive reference work abstracts and indexes the contents of publications in all languages and in all fields of science relating to the Arctic and sub-arctic regions of the world. Volume 8, containing abstracts of 5,623 publications in 1,281 pages, was scheduled for publication by the Government Printing Office early in July 1959, and work on volume 9 is underway. Subject fields receiving special emphasis in volume 8 include body systems, human and other; botany; construction; disease; ecology; economic and social conditions; environmental effects

of darkness, light, and low temperature on man, animals, and plants; Eskimos; expeditions, especially Russian; fishes and fisheries; frost-bite; geology; hypothermia; ice and ice conditions; insects; meteorology; physiology, human and animal; Siberian native peoples; snow; transportation. These and some 230 other topics are listed alphabetically in the index and, as necessary, also under the name of the particular locality or major geographical region to which they pertain. Heretofore the *Arctic Bibliography* has been supported almost entirely by the Department of Defense. During the past year additional generous support has been provided by the National Science Foundation, the National Institutes of Health, and the National Geographic Society.

Dr. Collins also made plans for a Russian translation project whereby the Arctic Institute, with the support of the National Science Foundation, would make available to American anthropologists translations of Russian publications on the archeology, ethnology, and physical anthropology of Siberia.

Dr. William C. Sturtevant, ethnologist, spent the first part of the fiscal year in Washington at work on various projects related to his Seminole and Seneca research. He also prepared for publication a paper on the economic uses of *Zamia*, a cycad with a large underground stem from which starch has been extracted for centuries by various Indian and other inhabitants of the West Indies and Florida. Another paper brought to completion reconsiders, with negative results, the ethnological evidence for contacts between Indians of the southeastern United States and the West Indies (previously widely considered to have been quite significant for the history of the culture of the southeastern tribes). Brief papers were completed on the history of the classification of eastern Siouan languages (published in *American Anthropologist*), on the authorship of J. W. Powell's famous classification of North American Indian languages published by the Bureau of American Ethnology in 1892, and on two new techniques for ethnographic fieldwork. Dr. Sturtevant's pamphlet "Anthropology as a Career," issued by the Institution in July 1958, proved so useful to students and their advisers throughout the country that a second printing was required in May 1959.

In mid-February Dr. Sturtevant left for Florida to begin 6 months' fieldwork among the Seminole Indians, with the support of a grant from the National Science Foundation. This was a continuation of the fieldwork Dr. Sturtevant conducted among these people before joining the Smithsonian staff. Besides filling in gaps in information obtained during previous trips, Dr. Sturtevant has concentrated on studying Seminole knowledge and uses of plants, both wild and cultivated. These Indians are the only ones in the eastern United

States who still use agricultural techniques once common to all the Indians of this region but heretofore undescribed by careful observers. Fields are cleared by cutting and burning, planted without fertilizer, and soon abandoned for new fields when fertility decreases and weeds become difficult to control. In addition to the ancient North American Indian crops—corn, pumpkins, and beans—the Seminole grow a number of plants that were introduced from the West Indies during and after the 18th century (banana, sugarcane, sweetpotato, taro, elephantear [*Xanthosoma*], manioc, papaya, guava, citrus). Seminole knowledge of wild plants is also extensive, and they still use many of them for medicine, food, and in the manufacture of utensils and other artifacts. Dr. Sturtevant found that at least two dozen fields are being cultivated with aboriginal methods, but intensive study of these fields and other aspects of Seminole society and culture has been even more difficult than he anticipated, owing largely to increased political factionalism and antagonism toward inquisitive outsiders.

Dr. Sturtevant compiled genealogical information preparatory to collaboration with Dr. John Buettner-Janusch, a physical anthropologist at Yale University, on a study of the genetic characteristics (chiefly blood groups) of the Seminole, who certainly have fewer non-Indian ancestors than any other surviving eastern tribes.

Besides collecting herbarium specimens of plants used and recognized by the Indians, Dr. Sturtevant made an ethnological collection to supplement the Seminole holdings of the National Museum. He paid particular attention to clothing, since Seminole styles have changed rapidly but are still unique in many respects, and objects made for sale. The latter are an important part of Seminole economy and involve objects quite different from those usually made for sale by other tribes.

Dr. Wallace L. Chafe, ethnologist, joined the staff of the Bureau in April but did not report for duty until June as he was completing teaching duties at the University of Buffalo. Dr. Chafe spent the 3 weeks before departing on June 29 in preparing for fieldwork on the Seneca reservations in western New York State. He will gather material that will enable him to complete a Seneca dictionary and will make further tape recordings of religious and mythological texts. This work was started under the sponsorship of the New York State Museum and Science Service and is being continued as a cooperative effort.

On June 3, 1958, Carl F. Miller was temporarily transferred from the staff of the River Basin Surveys to that of the Bureau of American Ethnology in order that he might continue directing the excavations of the Smithsonian Institution-National Geographic Society

Expedition which had been started in 1956 at Russell Cave in Alabama. This third season of work continued through September 29 and brought to completion the investigations at that site. Russell Cave has contributed extensive information pertaining to Indian peoples who inhabited that area over a considerable period of time. Several cultural horizons are represented, the earliest of which is some $9,020 \pm 350$ years old on the basis of carbon-14 dating of charcoal from a hearth at that level. The first peoples apparently had a completely hunting-fishing economy and from that progressed through what is called the Archaic period to a more sedentary mode of life and became makers of pottery. The latter handicraft appeared at about 3500 B.C. The culture subsequently developed into what is known as the Early Woodland and continued through stages known as Middle and Late Woodland. It was during these three stages that agriculture became a part of their economy. The latest occupation seems to have been by Chickamauga Cherokee Indians in the early 1600's. During the 1958 season Mr. Miller reached the original and lowest floor in the cave, some 43 feet below the present floor. However, no evidence of occupation was found below the 37-foot level. During the course of the digging he found a fifth burial which helped to throw additional light on the mortuary customs of the people who inhabited the cave.

While in northern Alabama, Mr. Miller visited several other caves, also Indian sites in the open, and studied many local collections in order to correlate the cultural remains from Russell Cave with those of the surrounding areas, particularly those attributable to Early Man phases. Mr. Miller also spoke before different groups of people in Bridgeport and Huntsville, Ala., and in South Pittsburg, Richard City, and Tullahoma, Tenn. Following his return to Washington on October 4, Mr. Miller devoted his time to the preparation of reports. In November and December he attended meetings of the American Indian Ethnohistoric Conference and the American Anthropological Association in Washington, D.C., and was one of the speakers at the Southeastern Archeological Conference in Chapel Hill, N.C. Mr. Miller returned to duty on the River Basin Surveys staff December 14, 1958.

RIVER BASIN SURVEYS

The River Basin Surveys continued its program for salvage archeology in areas to be flooded or otherwise destroyed by the construction of large dams. These investigations were carried on in cooperation with the National Park Service and the Bureau of Reclamation of the Department of the Interior, the Corps of Engineers of the Department of the Army, and several State and local institutions. Dur-

ing the fiscal year 1958-59 the work of the River Basin Surveys was supported by a transfer of \$162,000 from the National Park Service to the Smithsonian Institution. Of that sum, \$137,000 was for use in the Missouri Basin and \$25,000 was for investigations along the Chattahoochee River in Alabama and Georgia. The Missouri Basin Project had a carryover of \$22,173 on July 1, 1958, and that, with the new appropriation, provided a total of \$159,173 for the program in that area. The grand total of funds available for the River Basin Surveys for 1958-59 was \$184,173.

Field investigations throughout the year consisted mainly of excavations, although some limited surveys were carried on. On July 1, 1958, 10 parties were in the field, all of them working in the Missouri Basin in South Dakota. Five of the parties were doing intensive digging in the Big Bend Reservoir area near Fort Thompson, four were excavating, and one was doing survey testing in the Oahe Reservoir area north of Pierre. Most of the field parties had returned to their headquarters at Lincoln, Nebr., by the end of August. Two small parties made brief investigations in the Merritt and Big Bend Reservoir areas during December and January. In February three parties began excavations and test excavations along the Chattahoochee River in Alabama-Georgia. The latter continued operations until late in June, when work was stopped and the men returned to their headquarters. Early in June a party from the Missouri Basin project headquarters began excavations in several sites in the construction area for the Big Bend Dam in South Dakota.

As of June 30, 1959, reservoir areas where archeological surveys had been made or excavations carried on since the beginning of fieldwork by the River Basin Surveys in the summer of 1946 totaled 254, located in 29 States. Two lock projects and four canal areas had also been examined. The survey parties have located 4,909 archeological sites, and of that number 1,017 have been recommended for excavation or limited testing. The term "excavation" in this respect does not imply the complete uncovering of a site, but rather digging only enough of it to obtain a good sample of the materials and information to be found there. While many of the locations are unquestionably of sufficient importance to warrant complete excavation, the needs of the salvage program make it impossible to conduct so extensive an investigation at any one location.

Preliminary appraisal reports have been issued for all the reservoir areas surveyed, with the exception of the three along the Chattahoochee River. The manuscripts of two of those reports have been completed and the third is well underway, so that all of them will be processed early in the coming fiscal year. The preliminary appraisal report for the Big Bend Reservoir area in South Dakota was mime-

ographed and distributed in October 1958. Since the start of the Inter-Agency Archeological Salvage Program, 185 appraisal reports have been issued. In a number of cases the information obtained from several reservoir projects located within a single basin or sub-basin have been combined in one report and for that reason there is a discrepancy between the number of reservoirs surveyed and that of the reports issued.

At the end of the fiscal year, 434 sites in 54 reservoir basins located in 19 different States had been either partially or extensively dug. In some reservoir areas only a single site was excavated, while in others a whole series was studied. At least one example of each type of site recommended by the preliminary surveys had been investigated. Where some of the larger and more complex types of village remains were involved, it was necessary to dig a number of somewhat similar sites in order to obtain full information about that particular phase of aboriginal culture. The sites investigated represent cultural complexes ranging from the early hunting peoples of approximately 10,000 years ago to early historic Indian village remains and frontier trading and army posts of European origin. Reports on the results obtained in some of the excavations have appeared in the Smithsonian Miscellaneous Collections, in Bulletins of the Bureau of American Ethnology, and in various scientific journals. During the year River Basin Surveys Papers Nos. 9 through 14, comprising Bulletin 166 of the Bureau of American Ethnology, were published and distributed. The papers consist of three reports on excavations in the Missouri Basin, one on digging in the Alatoona Reservoir in Georgia, one on investigations in six sites in the Jim Woodruff Reservoir basin in Florida, and one on historic sites in and adjacent to the Jim Woodruff Reservoir area in Florida-Georgia. The Missouri Basin reports were written by Paul L. Cooper, Robert B. Cumming, Jr., and Carlyle S. Smith and Roger T. Grange, Jr. Those pertaining to the Southeast were prepared by William H. Sears, Mark F. Boyd, and Ripley P. Bullen. River Basin Papers Nos. 15-21, which will constitute Bulletin No. 176 of the Bureau of American Ethnology, were sent to the printer in March. That series of papers pertains to studies in historic sites in the Fort Randall, Oahe, and Garrison Reservoir areas in South Dakota and North Dakota. Nine detailed technical reports were completed during the year and are ready for publication when the funds sufficient to cover their cost are available. In addition, the first and second drafts of seven technical reports were finished. The final drafts should be ready early in the next fiscal year.

As of June 30, 1959, the distribution of the reservoir projects that had been surveyed for archeological remains was as follows: Alabama, 4; Arkansas, 1; California, 20; Colorado, 24; Georgia, 8; Idaho,

11; Illinois, 2; Iowa, 3; Kansas, 10; Kentucky, 2; Louisiana, 2; Minnesota, 1; Mississippi, 1; Montana, 15; Nebraska, 28; New Mexico, 1; North Dakota, 13; Ohio, 2; Oklahoma, 7; Oregon, 27; Pennsylvania, 2; South Carolina, 1; South Dakota, 10; Tennessee, 4; Texas, 19; Virginia, 2; Washington, 11; West Virginia, 2; Wyoming, 22.

Excavations were made or were underway in reservoir basins in: Arkansas, 1; California, 5; Colorado, 1; Iowa, 1; Georgia, 7; Kansas, 5; Montana, 1; Nebraska, 1; New Mexico, 1; North Dakota, 4; Oklahoma, 2; Oregon, 4; South Carolina, 2; South Dakota, 4; Texas, 7; Virginia, 1; Washington, 4; West Virginia, 1; Wyoming, 2. Only the work of River Basin Surveys or that which was in direct cooperation between the Surveys and local institutions is included in the preceding figures. Investigations carried on under agreements between the National Park Service and State and local institutions have not been included because complete information about them is not available.

Throughout the year helpful cooperation was received from the National Park Service, the Bureau of Reclamation, Corps of Engineers and other Army personnel, and various State and local institutions. The Corps of Engineers provided transportation and guides for work in one of the reservoir areas and the Commanding Officer at Fort Benning in Georgia assigned certain Army personnel to assist in some of the investigations made in that portion of the Walter F. George Reservoir basin which lies in the Fort Benning Reservation. Helicopters were also furnished on several occasions to enable the archeologists to take aerial photographs of several sites in the reservoir area. In the Missouri Basin temporary headquarters and living accommodations were provided at several projects and storage space was made available so that much of the field equipment could be left at Pierre, S. Dak., during the winter months. The construction agency lent mechanical equipment in several instances to assist in heavy excavation and the backfilling of trenches and test pits. The various party leaders from the River Basin Surveys were given assistance by field personnel of all the agencies and the work was greatly expedited as a result. The National Park Service continued to serve as the liaison between the various agencies in the field as well as in Washington. The estimates and justifications for the funds needed to carry on the salvage program were also prepared by the Park Service. In Georgia the University of Georgia, the Georgia Historical Commission, and various local clubs and groups of citizens were particularly helpful to the parties working along the Chattahoochee River.

The main office in Washington continued general supervision of the program, while the field headquarters and laboratory at Lincoln, Nebr., was responsible for the activities in the Missouri Basin, and in addition provided equipment and office assistance for the parties engaged in the Chattahoochee River project. The materials collected by excavating parties in the Missouri Basin, as well as those from the Chattahoochee Basin, were processed at the Lincoln laboratory.

Washington office.—The main headquarters of the River Basin Surveys at the Bureau of American Ethnology continued under the direction of Dr. Frank H. H. Roberts, Jr. As previously mentioned, Carl F. Miller, archeologist, was detailed to the regular Bureau staff for the period July 3 to December 14, 1958. After his return to the River Basin Surveys staff, Mr. Miller completed the final revision of his report on the "Archeology of the John H. Kerr Reservoir, Southern Virginia and Northern North Carolina." The report includes a summary of the many sites located during the course of the original survey of the area, as well as detailed information on those which were excavated by Mr. Miller. After submitting the John H. Kerr report, Mr. Miller began work on the final report pertaining to the investigations that he made at the Hosterman site (38PO7) in the Oahe Reservoir area, South Dakota, during a previous field season. The report was approximately one-half complete at the end of the year. During the winter and spring months Mr. Miller spoke before several teachers' organizations in the Washington area, addressed a meeting of the Narragansett Archeological Society at Providence, R.I., the Archeological Society of Virginia in Richmond, and the Southern Branch of the Archeological Society of Maryland at Bethesda, Md. Most of his talks pertained to the Russell Cave explorations, although the one given at Bethesda compared the materials from the John H. Kerr Reservoir with those from the Shepard Barracks site in Maryland where excavations were carried on by the Maryland Society. In June, Mr. Miller read proof on an article about Russell Cave, which is to appear in a book on National Parks and Monuments in the United States being issued by the National Geographic Society. In January Mr. Miller received the Franklin L. Burr Award from the National Geographic Society in "recognition of his outstanding contributions to the science of geography and early American history through the archeological investigations of Russell Cave, Alabama." At the end of the fiscal year Mr. Miller was working in the Washington office.

On October 13, 1958, Harold A. Huscher was transferred from the Missouri Basin project to the Chattahoochee River project. He was under the general supervision of the Washington office but continued to work at the headquarters in Lincoln, Nebr., where he

completed reports on the surveys made during the previous year at the Oliver and Columbia Reservoir projects on the Chattahoochee River. He also virtually completed the first draft of his preliminary appraisal of the archeological explorations in the Walter F. George Reservoir area. In early February, Mr. Huscher returned to the Chattahoochee Basin and from then until late June carried on a series of investigations in the Columbia and Walter F. George Reservoir basins. While working in Alabama and Georgia, Mr. Huscher spoke before numerous clubs and local groups, took part in several radio broadcasts devoted to archeological problems along the Chattahoochee River, and appeared on several TV broadcasts. He returned to the field headquarters at Lincoln, Nebr., on June 30.

In February, Robert W. Neuman and G. Hubert Smith were transferred to the Chattahoochee River project and under general direction from the Washington office proceeded to that area. Mr. Neuman, during the period February 9 to June 23, carried on excavations in the vicinity of the Columbia Dam axis in Georgia and did test digging in one large mound on the Alabama side of the river. While in Georgia, Mr. Neuman spoke before various local clubs and groups of interested citizens. He also appeared on a TV interview pertaining to the salvage program and spoke before the Macon, Ga., Archeological Society. He returned to the field headquarters at Lincoln, Nebr., on June 27. Mr. Smith worked at two locations in the Walter F. George Reservoir area, one in Georgia and one in Alabama. He also talked before a number of local organizations. Mr. Smith returned to the field headquarters on June 17.

Alabama-Georgia.—During the period February through June a series of test excavations was carried on at a number of sites in the areas to be flooded by the Columbia Dam and Lock and the Walter F. George Dam and Lock. Robert W. Neuman worked in seven sites on the Georgia side of the Chattahoochee River in the vicinity of the Columbia Dam axis. Six of the sites dated from the Archaic period and extended into Middle Woodland times. The seventh site on the Georgia side represented a historic Creek occupation dating about A.D. 1830. A good collection of materials was obtained from all these sites and the specimens will aid materially in working out the cultural stages in that area. On the Alabama side of the river Mr. Neuman excavated in the remains of a large mound which was being destroyed by the river. Some work had been done there many years ago by Clarence W. Moore, but there was little information pertaining to the general character of the mound. Mr. Neuman obtained information relative to the method of its construction and several stages in its growth. Further work is contemplated at the site.

Harold A. Huscher carried on a series of excavations in four sites on the axis of the Columbia Dam $2\frac{1}{2}$ miles below Columbia, Ala. The area is one of extensive sandy bottoms and, with minor variations, the sites produce Weeden Island pottery types in the surface levels and to a depth of about 2 feet. There is also a scattering of Stallings Island potsherds, steatite fragments, and large heavy-stemmed projectile points down to about $4\frac{1}{2}$ feet below the surface. Some of the flint flakes and points from the deeper levels have been completely altered chemically to a chalky residue. Similar points were found previously on the Macon plateau by Dr. A. R. Kelley and were described by him in Anthropological Paper No. 1, which appeared in Bulletin 119 of the Bureau. Mr. Huscher made maps and detailed excavation plans for these sites.

Construction work was underway on the Walter F. George Dam in early February and Mr. Huscher made a series of 10- by 10-foot test excavations in three sites which were threatened with immediate damage. One of them at the Georgia end of the dam axis yielded a variety of trade goods, including the mechanism of a flintlock. The site probably represents the location of a Creek village of about A.D. 1800. Another site on the Georgia side, a short distance above the dam, and one on the Alabama end of the dam axis, produced plain Early Mississippian pottery. The material from the Alabama site indicated pottery with angled-loop handles similar to the ware that has been called Bibb Plain. The pottery from the Georgia site had flat strap handles with vertical incised decoration. The pottery characteristics are so definite that it is possible to correlate the wares with those from other sites in the general area.

Mr. Huscher later moved upstream and began the investigation of two sites on the Fort Benning Military Reservation. One of them on the Georgia side is an Early Lamar site and seems to contain a single "pure" component. The site had been destroyed to a large extent by Army bulldozers building a road, but trenches in two separate remnants revealed post-hole patterns that apparently represented two rectangular houses. A nearby midden area yielded a good representative sample of pottery types associated with the houses. The second site was on the Alabama side of the river just north of Uchee Creek. It is a Swift Creek-Weeden Island site and has an older underlying level. Sgt. David W. Chase, curator of the Infantry Museum at Fort Benning, Ga., had done some work there, and because of the evidence he had obtained, indicating that it would be a type site for the Swift Creek-Weeden Island phase of Middle Woodland in the area, it was extensively tested by the Huscher party. Beneath the Middle Woodland levels in a portion of the site there is a bed of white sand which has yielded fiber-tempered potsherds of

the Stallings Island type and fragments from steatite vessels. This stratigraphic evidence augments that found in other locations along the river. Sergeant Chase turned over to the River Basin Surveys party extensive notes and collections resulting from his previous work at both sites. He also assisted Mr. Huscher in making detailed plane-table maps of the sites and plans of the excavations.

G. Hubert Smith excavated in two historic sites in the Walter F. George Reservoir Basin. One of them on the Georgia side of the river was the location of the village of Roanoke, a colonial settlement that had originally been occupied by Creek Indians but was subsequently taken over by the whites who lived there from 1831 until the community was destroyed by Indians in May 1836. Because of the long period in which the area was under heavy cultivation, Mr. Smith was unable to determine the settlement pattern or to obtain outlines for any of the village structures. He did, however, obtain an extensive collection of specimens attributable both to the white occupation and that by the Indians. Careful study of the material may provide information that will be useful in dating some of the other late Indian sites along the river. From the Roanoke site Mr. Smith went to one on the Alabama side in Russell County, which was the location of a fort built and occupied by the Spaniards from 1689 to 1691. The fort known as Apalachicola was probably the most northern outpost of the Spanish occupation in the Southeast and was erected for the purpose of stemming the southward expansion of the English. The Spaniards possibly did not occupy the fort continuously, but lived at times in an adjacent Indian village. The fort was destroyed by the Spaniards to prevent its falling into the hands of English traders from the Carolinas who were operating among the Creek Indians. Mr. Smith did not dig in the fort proper but confined his investigations to the area immediately surrounding it in order to delimit the extent of the fortifications and to determine the proximity of Indian occupation. The fort remains will not be subjected to flooding by the Walter F. George Reservoir, but the maximum pool level will not be far distant and may damage the remains to some extent as a result of seepage. Consequently it is thought that a thorough study should be made of the site at a later date. Furthermore, associations between Spanish and Indian objects will provide a helpful checking point in establishing chronology of the area, particularly since the exact dates for the fort are known. After completing the investigations at the two sites, Mr. Smith assisted Mr. Huscher in making detailed plane-table maps and trench plans for both.

In addition to the test excavations described above, Mr. Huscher located and recorded 10 new sites in the Walter F. George and Columbia areas and made collections from 46 sites. At the end of the

season's work along the Chattahoochee, all the records and collections of the three field parties were sent to the laboratory of the River Basin Surveys at Lincoln, Nebr., for processing there and for use in the preparation of reports on the investigations.

The only other work by the River Basin Surveys pertaining to Georgia was that of Carl F. Miller, who completed a report on the test digging that he did during the previous year at the Tugaloo site in the Hartwell Reservoir area. However, the University of Georgia in cooperation with the National Park Service carried on a series of investigations in the Oliver Reservoir Basin and at the Standley Farm site, also known as Stark's Clay Landing, in the Walter F. George Reservoir on the Georgia side of the river. Work was continuing at the latter location at the end of the fiscal year.

Arkansas.—No fieldwork was carried on in Arkansas during the year ended June 30, 1959. However, a detailed technical report, "Archeological Investigations in the Dardanelle Reservoir Area of West-Central Arkansas," was completed by Dr. Warren W. Caldwell. The report consists of 85 typed pages, 2 maps, 8 plates, and 6 text figures. It will be published as a River Basin Surveys paper when printing funds for that purpose are available.

Kansas.—The only work done by the River Basin Surveys pertaining to Kansas during the fiscal year was the completion of a detailed technical report on the excavation of four sites in the Lovewell Reservoir area on White Rock Creek in Jewell County in the north-central part of the State. The report was written by Robert W. Neuman and is entitled, "Archeological Salvage Investigations in the Lovewell Reservoir Area, Kansas." It consists of 84 typed pages, 12 plates, and 3 text figures, and will be published as a River Basin Surveys paper.

The Kansas State Historical Society at Topeka carried on surveys and did some test digging in the Pomona and Melvern Reservoir areas under a cooperative agreement with the National Park Service. The Pomona Dam is to be built on the 110-Mile Creek, and Melvern Dam will be in the Marais de Cygnes River.

Missouri River Basin.—The Missouri Basin project continued to operate from the field headquarters and laboratory at 1517 O Street, Lincoln, Nebr. Dr. Robert L. Stephenson served as chief of the project throughout the year. Activities included work on all four phases of the salvage program: (1) Survey, (2) excavation, (3) analysis, and (4) reporting. Most of the effort during the summer months was directed toward the second phase, with only minor attention to the first phase. The third and fourth phases received the major attention in the winter months. The special chronology program, begun last fiscal year, was continued.

At the beginning of the fiscal year the permanent staff, in addition to the chief, consisted of six archeologists (one of whom was on loan to the National Park Service), one clerk-stenographer, one file clerk, one clerk-typist, one photographer, one illustrator, and four museum aides. Temporary employees included 1 archeologist, 1 physical anthropologist, 2 field assistants, 3 cooks, and 90 crewmen.

During the year, 1 archeologist was transferred to the staff from the Chattahoochee Project on July 21, 1 cook joined the temporary staff on July 9, and 16 temporary crewmen were added in July. During the last week of August and the first week of September, all temporary crewmen and three cooks were terminated, and one cook was transferred from that position to laboratory assistant. The temporary archeologist was terminated on September 12, and the two field assistants were terminated on August 29 and September 5, respectively. The physical anthropologist was terminated on September 2, and one museum aide was transferred from full time to half time on September 15. The archeologist on temporary-detached duty with the National Park Service returned to the permanent staff on October 1. One archeologist was transferred on October 13 to the Chattahoochee Basin project.

On September 23, one archeologist was assigned temporary-detached duty for 8 weeks with the National Park Service to conduct excavations at Fort Laramie National Monument, Wyo. He returned to the Missouri Basin project on November 15. On December 4, one archeologist was assigned temporary-detached duty for 3 weeks with the National Park Service to conduct excavations at George Washington Carver National Monument, Mo. He returned to the Missouri Basin project on December 21. On February 9, two archeologists were transferred for temporary duty with the Chattahoochee Basin Project. They returned to the Missouri Basin project on June 17 and 29, respectively. One museum aide resigned to take other employment on March 20, and one archeologist was permanently transferred to the National Park Service on May 30, to join the staff of the Wetherill Mesa Research project, Mesa Verde National Park, Colo. During June, six temporary crewmen were employed.

At the end of the fiscal year there were five archeologists, in addition to the chief, one administrative assistant, one clerk-stenographer, one file clerk, one clerk-typist, one illustrator, one photographer, and three museum aides on the permanent staff, and one laboratory assistant and six crewmen on the temporary staff.

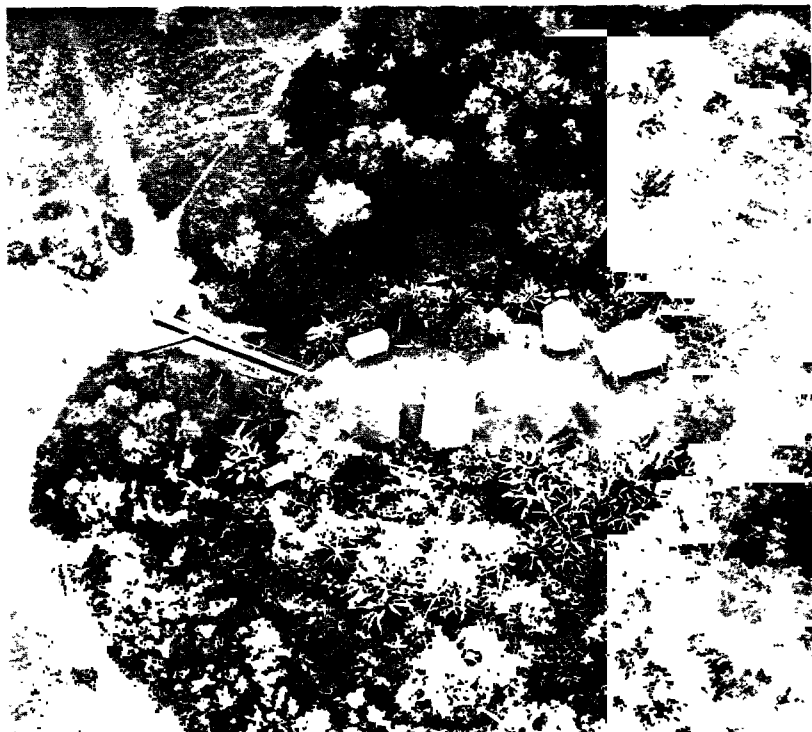
During the year there were 14 Smithsonian Institution River Basin Surveys field parties at work within the Missouri Basin. Of the 14 Missouri Basin parties, 5 were at work in the Oahe Reservoir area during July and August, and 5 others were at work in the Big Bend

Reservoir during July and August. Two small parties were at work during December and January, respectively, in brief investigations in the Merritt and Big Bend Reservoir areas. One party was at work in the Big Bend Reservoir area and a second (mobile) party was working in the general Missouri Basin area in June.

Other fieldwork in the Missouri Basin during the year included 10 parties from State institutions operating under cooperative agreements with the National Park Service and in cooperation with the Smithsonian Institution in the Inter-Agency Archeological Salvage Program.

At the beginning of the fiscal year, in the Oahe Reservoir area, Dr. Robert L. Stephenson and a crew of 20 men were engaged in excavations at the Sully site (39SL4). This was the third and final season of work at this, the largest of the earth-lodge village sites in the Missouri Basin. The site was situated on the second terrace of the Missouri River, 21 miles above Pierre, in Sully County, S.Dak. The 1958 investigations were concentrated largely in the central and eastern portions of the site. These, with those of the two preceding seasons, provided a reasonably equal sample of features and specimens from all portions of the site. Excavation technique differed somewhat in the 1958 season. During the 1957 season, whole houses were excavated, but the surrounding areas outside were not examined. In 1958 only one house was excavated in this manner. In the other excavation units, only half houses were dug, but the surrounding areas on three sides of each house were also excavated. In this way portions of 19 houses were investigated, with most of the essential structural details obtained from all but two of them. Experience of the previous seasons' work at this site suggested that more could be learned of the total village pattern in this way, and that excavation of complete houses was neither necessary nor economically feasible. Besides the house areas, half of a ceremonial lodge, two large cache-pit areas, a scaffold area, a midden heap, and another portion of the "plaza" were also excavated, and two midden areas were tested. Thus all or parts of 32 of the nearly 400 houses have been excavated, as have been 3 of the 4 ceremonial lodges, a scaffold area, several cache-pit areas, midden heaps, and a "plaza." Numerous tests were made in an effort to locate a fortification ditch or stockade, but none was found.

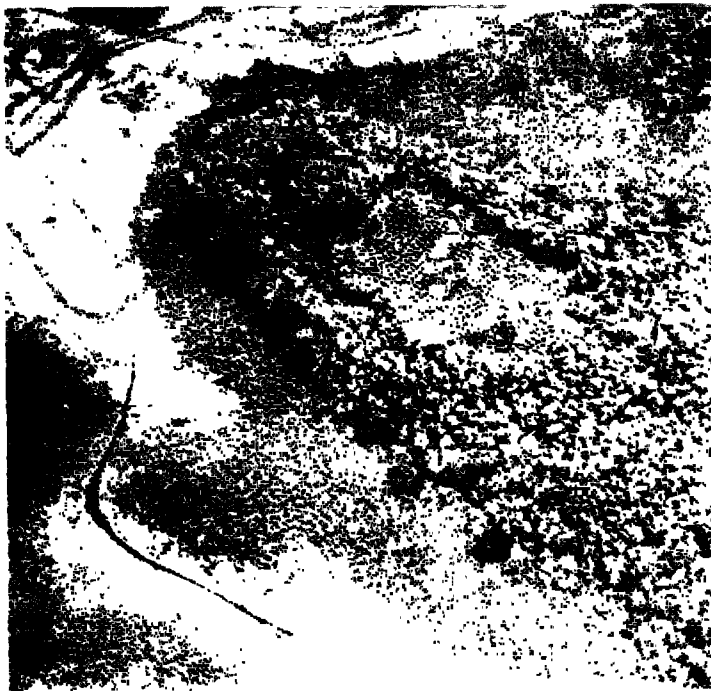
Emphasis was placed, in the field, upon securing architectural information, and good superposition of varying types of dwelling houses was obtained. Two distinct, circular, dwelling-house types were present, one with a series of widely spaced large wall posts of an early period, and one with a series of small, closely set wall posts of a later period. There was considerable variation within each type. The earlier type had short entryways, while the later one had medium-



1. Seminole settlement in the Everglades.



2. Digging up edible roots of elephant-ear (*Xanthosoma* sp.), a plant cultivated by the Seminole.



1. Aerial view of a Seminole field in the Everglades.



2. Corn growing in a Seminole field in the Big Cypress Swamp.



1. Excavation of Feature 1, a portion of a circular house exposed in slump bank along Missouri River at the Ziltener Site (59SL10) in the Oahe Reservoir area, South Dakota. Most of the house had washed away but the remainder was undisturbed, with a fair floor and post holes dug into soft silt. River Basin Surveys



2. Crew excavating remains at the Truman Mound Site (59BF224), a group of six burial mounds of the pre-earth-lodge peoples in the Big Bend Reservoir area, South Dakota. River Basin Surveys.



(See legend on opposite page.)

PLATE 4

Representative examples of pottery vessels from various sites in the Missouri Basin.

(a) From site 25FT17, an Aksarben Aspect site in Medicine Creek Reservoir, Nebraska. (b) From Leavitt Site (39ST215), Oahe Reservoir, South Dakota. (c) From White Swan Mound Site (39CH9), a Woodland Site in Fort Randall Reservoir, South Dakota. (d) From Leavitt Site (39ST215). (e) Stanley Tool Impressed vessel from Phillips Ranch Site (39ST14), Oahe Reservoir. (f) From Leavitt Site (39ST215). (g) Colombe Collared Rim vessel from Phillips Ranch Site (39ST14). (h) Foreman Cord Impressed vessel from Dodd Site (39ST30), Oahe Reservoir. (i) Mitchell Broad Trilled vessel from Dodd Site (39ST30). (j) From Cheyenne River Site (39ST1), Oahe Reservoir. (k) Stanley Braced Rim vessel from Dodd Site (39ST30). (l) Truman Plain Rim vessel from Truman Mounds Site (39BF224), Big Bend Reservoir, South Dakota. (m) From White Swan Mound Site (39CH9). (n) From Site (48FR84), Boysen Reservoir, Wyoming. Only known restored vessel from Wyoming. (o) From Leavitt Site (39ST215).

to-long entryways. The earlier houses were of rather uniform size (about 36 feet in diameter), while the later ones ranged from 19 feet to 47 feet in diameter. A unique feature was the presence of two concentrically superimposed ceremonial lodges, using almost the same floor level. One was 77 feet in diameter, superimposed upon one that was 64 feet in diameter. All the large ceremonial lodges excavated at the Sully site (as well as several of the later dwelling houses) were actually polyhedral rather than round, and had between 9 and 12 sides.

All occupations of this site were relatively late, with both major components (additional minor components have yet to be differentiated) in the circular-house tradition and probably relating to the period between roughly A.D. 1600 and 1750. The pottery sample and other artifact inventory is large and varied, but no assessment of it has been made at this time. This field party disbanded on August 23, after 10 weeks in the field.

The second River Basin Surveys field party in the Oahe Reservoir area consisted of a crew of eight men, under the leadership of William M. Bass III, physical anthropologist. This party devoted the major part of the season to excavations in the burial areas of the Sully site (39SL4). This was a continuation of work begun in 1957 on a somewhat smaller scale. Work was concentrated in three areas (Features 218, 219, and 220) and 161 burials were recovered, bringing the number of burials excavated at the Sully site to 224. Only a preliminary analysis of the skeletal remains has been made. Bodies were interred in shallow oval pits dug into an old surface about 1 foot below the current soil level. Burials were predominantly flexed or semiflexed and oriented with the head toward the west or northwest. A group burial, recovered from Feature 218, appears to be the remnant of a scaffold burial. Many of the graves had a covering of small poles, but few had grave goods included. The grave goods that were recovered included pottery vessels, ornaments, and an occasional cat-linite pipe.

The Bass party, in addition to work at the Sully site, excavated nine rock-cairn burials at the Whistling Hawk site (39SL39), a rather ephemeral site on the same terrace 2 miles east of the Sully site. Burials were found in each cairn, but significant skeletal remains were scanty, as most of the bones were badly deteriorated. Artifacts with these burials were few.

At the end of the field season, the Bass party devoted a short period to the excavation and collection of a group of burials and associated artifacts from a site (39YK202) recently discovered in the course of U.S. Fish and Wildlife Service construction work near the Gavins Point Dam. Only the prompt action and complete cooperation

of the Commission, the local contractor, the Corps of Engineers, members of the Yankton College staff, the National Park Service, and the Smithsonian Institution made this salvage operation successful. The burials proved to be of a group of Woodland people and included an appreciable number of personal ornaments, as well as a good series of skeletal remains. This party disbanded on August 23, after 8 weeks in the field.

The third River Basin Surveys party in the Oahe Reservoir area at the beginning of the year was comprised of a crew of 10 men under the direction of Charles H. McNutt. This party conducted excavations at a series of sites in the Fielder Bottom-Telegraph Flat area near the Sully site. The work was a continuation of excavations begun the season before, designed to sample the smaller sites in the immediate vicinity of the Sully site, in order to round out the story of the prehistoric occupations of this once heavily populated area. At the Sully School site (39SL7), one house was excavated in its entirety, and portions of four more houses were exposed. Three test trenches were cut across the fortification ditch, and a large series of midden tests, cache pits, and subsidiary features were excavated. Because of the two seasons' work there the total artifact sample is extensive. The architectural information recovered is less satisfactory. The gumbo fill present in many of the features made it extremely difficult to determine structural characteristics. Two occupations were present, one represented by rectangular houses and pottery similar to that from the Thomas Riggs site, the other by circular houses and pottery in the La Roche tradition. Only part of the site was fortified. The rectangular-house occupation was confined within the fortification ditch, but the circular-house occupation was found both within and without the ditch. There is additional ceramic evidence that the fortification probably dates from the former, rather than from the latter, occupation.

The Ziltener site (39SL10) was located along a treeless cutbank of the Missouri River bottoms approximately 3 miles southeast of the Sully site. Informants had reported that a number of skulls and artifacts were eroded from the bank from time to time by the annual spring rises in the river. The bank was carefully watched for several seasons by River Basin Surveys parties, but with little success. In 1958 a storage pit and a house profile were visible, and a small cache was found where it had slumped from the cutbank. The remainder of the house and the storage pit were excavated. The house was circular, and the pottery of the La Roche tradition.

The Nolz site (39SL40) was located on a terrace remnant below and somewhat to the southwest of the Sully site. Three very faint house depressions were visible as surface features. Two of these

were trenched and the third was half excavated. Central hearths were found in all cases. Three additional tests were made on the site. Artifact recovery was fair, but architectural data were poorly represented, owing to the shallow depth of fill above house floors and the clayey nature of the soil. The houses were probably circular and the pottery in the La Roche tradition.

The Zimmerman site (39SL41), located on the same terrace as the Nolz site, consisted of a village area marked by about 40 large round-to-oval depressions. One rectangular house was excavated completely, and half the fill of a second was removed. A midden area and 12 cache pits were also excavated. There was no indication of the presence of any other component. Three exploratory trenches were dug, in an effort to find a fortification ditch, but no satisfactory ditch profile was discovered. The total data indicate that this was a single-component site, characterized by long-rectangular houses and Thomas Riggs pottery.

The Glasshoff site (39SL42) was situated on the Zimmerman-Nolz terrace below the west end of the Sully site. According to an informant, the area was once used for cavalry exercises by Fort Sully personnel. In the past, sherds were collected from the surface there, and one test excavation (1953) had provided additional evidence of aboriginal occupation. No well-defined house depressions were apparent, but several surface anomalies were visible. Wherever tested, they proved to be the result of activities attributable to the occupation of Fort Sully in the late 19th century. Trenching during the 1958 season yielded historic specimens, a cache pit, and a part of an aboriginal dwelling. The latter was found on the last day of the field season. Artifact recovery was fair, and although some architectural features were well preserved, few details were discernible. Pottery is simple-stamped and somewhat like the Thomas Riggs materials, but it appears to be a distinctive variant.

Site 39SL27, a large, unnamed site on Telegraph Flat, 1 mile east of the Sully site, has several visible but shallow "house" depressions. Three small pits dug in the centers of depressions yielded neither artifacts nor architectural features. Additional work is needed at this site.

The Whistling Hawk site (39SL39) comprised a large area along the edge of Telegraph Flat terrace, east of 39SL27. A single pit excavated into a deep (house?) depression yielded no artifacts or architecture, although the Bass party excavated rock-cairn burials at the site.

Two sites not situated in Fielder Bottom were also tested. Site 39SL19 was a low-lying area in the Little Bend region, 18 miles upstream from the Sully site. Two small, shallow pits were dug to

examine the fill, and the site was walked carefully. No indication of a village and no cultural material were found on the surface. This area will probably be flooded in 1959 and no further efforts there seem justified. The Pitlick site (39HU16), 8 miles downstream from the Sully site, is the northernmost site in the Peoria Bottom group. It will not be flooded in 1959, but will probably slump badly. Two large trenches and two deep test pits were excavated. One trench cut through the shoulder and floor of a house, the other through a fortification ditch. One of the deep test pits may have cut through a house floor. No artifacts were recovered at the site. This party disbanded on August 23, following 10 weeks in the field. The Stephenson, Bass, and McNutt field parties shared camp facilities near the Sully site in Fielder Bottom.

The fourth River Basin Surveys field party in the Oahe Reservoir area consisted of a crew of nine, directed by Richard P. Wheeler. It investigated a series of sites on the right bank of the Missouri River in the Fort Bennett area, 36 river miles above Pierre, Stanley County, S. Dak. The principal effort was directed toward excavations at the H. P. Thomas site (39ST12). A total of 60 circular earth-lodge depressions is apparent in area 1 of the site, and 21 depressions are suggested in area 2. Three lodges were excavated in area 1 and two in area 2. Overburden was removed from six additional lodges by bulldozer, and four dozer-cut trenches were carried across the moats in each area. Three midden deposits in area 1 were excavated, one containing a fragment of the floor pattern of a house. Three of the suggested five components appear to be assignable to the Snake Butte, Stanley, and Anderson-Monroe Foci, as defined by Lehmer for the Oahe Dam area.

At the Agency Creek site (39ST41), adjacent to site 39ST12, seven small test pits and one bulldozer trench were excavated. Since time did not permit detailed investigation of these sample excavations, little can be said of the cultural implications of the site, although laboratory analyses of the artifacts will prove informative. Additional tests were made at the Lounsbury site (39ST42) and at the Ramsey site (39ST236), the latter situated midway between 39ST41 and 39ST42. At the Lounsbury site, test pits were excavated into the centers of two circular-house depressions, exposing the central hearths. The overburden was bulldozed from the surface of one house, but the structure was not fully excavated. The Ramsey site appears to be a series of middens only, and a stratigraphic cut, 5 feet by 10 feet, provided an abundance of artifacts but no house remains. These test excavations at the Agency Creek, Lounsbury, and Ramsey sites yielded thin, horizontally incised rim sherds and simple-stamped body sherds characteristic of the Bennett Focus as suggested earlier

at the Black Widow (39ST3) and Meyers (39ST10) sites. This party disbanded on August 25 and returned to the headquarters in Lincoln after 10 weeks in the field.

The fifth River Basin Surveys field party in the Oahe Reservoir area began work on July 25. It consisted of Harold A. Huscher and a crew of two men and worked primarily on the left bank of the Missouri River in Stanley County, S. Dak. This survey-mapping-testing crew investigated a series of six sites along Black Widow Ridge, 3 to 6 miles above the H. P. Thomas site, mapping and testing each. They are sites 39ST25, 39ST50, 39ST3 (Black Widow), 39ST49, 39ST203, and 39ST201. The Huscher party mapped all four sites being excavated by the Wheeler party, 39ST12, 39ST41, 39ST42, and 39ST236, and mapped and tested three other sites some 10 miles below the H. P. Thomas site. These are sites 39ST37, 39ST38, and 39ST39. In addition, this party mapped and assisted the McNutt crew in testing the Pitlick site (39HU16) on the left bank of the Missouri River. Huscher was severely injured in a fall from a photographic ladder on August 24, thus terminating the work of this field party after 4 weeks in the field. Following 5½ weeks in the hospital and another month of recuperation, he returned to duty on October 13. The Wheeler and Huscher parties shared a joint field camp near Fort Bennett.

In the Big Bend Reservoir area there were five River Basin Surveys field parties at work at the beginning of the fiscal year. The first consisted of a crew of 12 men under the direction of William N. Irving and included an assistant trained in geology to aid in investigations of stratigraphic terrace sequences relating to the geological-archeological interpretations of the sites and their immediate vicinity. This party concentrated its efforts on the excavation of the early occupations of the Medicine Crow site (39BF2), begun last season, and other preceramic sites in the immediate vicinity. These sites are located near Old Fort Thompson on the left bank of the Missouri River, in or near the construction area of the Big Bend Dam, Buffalo County, S. Dak. At the Medicine Crow site, three major occupation zones, each containing two or more components, are distinguishable on the basis of the vertical distribution of point types within a 3- to 6-foot section of primarily aeolian silt. The basal section of a small fluted point was found in the lowermost occupation zone. From the same zone, however, came points that resemble those of the Frontier Complex, and others suggesting a long temporal range for the basal portion of the deposit.

Additional investigations were made at two sites, 39BF238 and 39BF250, that had not been recorded previously, and at the Aiken site (39BF215). Only at the latter were immediately significant re-

sults obtained. Limited excavations there indicated five occupational layers and two well-defined, buried soils. At least two ceramic horizons are present, in the upper levels, one with simple-stamped or plain pottery, the other with cord-marked body sherds. Several additional occupations, in stratigraphically earlier positions, have yielded neither pottery nor other diagnostic artifacts. The great depth of deposit and the presence of buried soils may make possible a considerable refinement in the stratigraphy of late preceramic remains in the Big Bend Reservoir area. Geological investigations carried on by Alan H. Coogan in the area of the lower portion of this reservoir were intended to obtain information bearing upon chronology and the environmental sequence of the Medicine Crow, Aiken, and other early sites in the area. The possibilities for correlation of terrace, moraine, and other depositional features appear to be excellent. The Irving party disbanded on September 4 and returned to the Lincoln headquarters after 13 weeks in the field.

The second River Basin Surveys party in the field in the Big Bend Reservoir area was a crew of 11 men under the direction of James J. F. Deetz. This party spent the entire season in excavation of the late (village occupation) components (areas B and C) of the Medicine Crow site (39BF2). The work was done in conjunction with that of the Irving party in an effort to provide a comprehensive picture of the site as a whole. In all, 16 houses were completely excavated, and 4 were tested with varying intensity. Included within the houses were 16 cache pits. Eleven cache pits were excavated in the interhouse living areas. A single burial was recovered. Three well-defined components have been established for the ceramic period of this site and a fourth, less adequately outlined component is proposed. The Stanley Component (latest) is characterized by a predominance of Stanley Braced Rim pottery; circular houses, 25 to 30 feet in diameter with hard, light-colored floors; mortar pits; and absence of interior cache pits. Five domestic and four specialized house structures are included in this component. The specialized houses were grouped about a "plaza" and included a ceremonial lodge, 50 feet in diameter, with an altar, plastered floor, and silled entrance. The Fort Thompson Component resembles that at the Oacoma site, but may be somewhat later. Talking Crow ware predominates. Houses range from 35 to 40 feet in diameter, have vaguely defined floors, in-floor caches, and lack mortar pits. Four such structures were excavated during the 1958 season. There were two cases of superimposition, with Stanley houses above Fort Thompson houses. A third, unnamed, component is represented by a series of large bell-shaped cache pits excavated in area C. These affiliate most closely with the Two Teeth site (39BF204) a short distance to the southeast. Talking

Crow Straight Rim pottery predominates. The fourth component, occurring in area A, is represented by a house with an indistinct post pattern buried in Stanley and Fort Thompson refuse. The associated ceramics are varied, and at this time no definite assessment can be made of them.

The investigations in areas A and C at the Medicine Crow site represent the first clear-cut Stanley occupation excavated south of the Oahe Reservoir. It is also important to note that a temporal relationship can now be established between the components involved. European trade materials found in association with Stanley features may be helpful in providing absolute dates for the latest occupation. The Deetz party terminated fieldwork on August 30 after 12 weeks in the field.

The third River Basin Surveys party in the Big Bend Reservoir was comprised of a crew of 10 men, under the leadership of Robert W. Neuman. This party excavated or tested a series of four sites in the vicinity of Old Fort Thompson and three sites on the right bank of the Missouri River, in and adjacent to Good Soldier and Counselor Creeks. All seven sites are within the dam-construction area. The initial effort was devoted to the Akichita site (39BF221) located in the Missouri River bottoms adjacent to Old Fort Thompson. The site had been tested during the 1957 season, but although extensive evidence of occupation was recovered, no house structures were found. A network of five extended test trenches, excavated during the 1958 season, was equally unsuccessful in locating habitations. Cache pits were the only structures uncovered. The artifact collection is extensive, and shows clear relationship to the Anderson-Monroe material from the Dodd site (39ST30) near Pierre, S.Dak. At site 39BF220, situated about 1 mile west of the Akichita site, much of the occupation area has been washed into the river. Two excavation units, each 30 feet by 50 feet, produced only a limited artifact return. However, a number of pottery types were recovered. The inventory suggests that the site was occupied by circular-house people.

The Truman Mound site (39BF224), also in the Old Fort Thompson area, on the first terrace overlooking the river, was revisited for a second season in order to excavate the remaining two of the six mounds originally present there. The mounds, 1 to 2 feet in height, 50 feet in diameter, contained two types of burials: (1) secondary interments in shallow circular pits, (2) primary burials in deep oval pits. Artifact material recovered from the site suggests Woodland affiliation, but the conical-shaped vessels excavated are clearly simple-stamped, rather than the Woodland cord-marked type. In a stratum beneath, and not associated with the mounds, excavations recovered a number of stone artifacts. The most diagnostic type is represented by a tri-

angular point with a concave base. In the same stratum were ovoid knives, crude scrapers, a long-stemmed drill, hand-size cobbles, and fragments of bison bone. No pottery was in association. Site 39BF270, located about 2 miles west of 39BF224, consisted of four low circular mounds, three of which were excavated. The recovered artifacts compare closely with those from the Truman Mound site.

At site 39LM238, on the west side of the Missouri at the mouth of Good Soldier Creek, where the west abutment of the dam is to be built, a large "mound" was extensively cross-trenched and a series of test pits were excavated in an effort to locate village remains. The "mound" proved to be of natural origin (165 feet long, 90 feet wide, 5 feet high) but capped by two occupational deposits separated stratigraphically by a stratum of sterile yellow silt. The upper component contained simple-stamped pottery, triangular points, scattered post molds (many with bone wedges), and a few shallow firepits. The lower component contained cord-paddled pottery, large side-notched points, shallow basin-shaped firepits, and a large rock-filled hearth. A small rock shelter (39LM239), located about a mile and a half upstream from Good Soldier Creek, was briefly tested. It was thought that this site might possibly be the "Truteau Cave," historically known to have been used as winter quarters by the trader Truteau in 1794. Excavation demonstrated the shelter to be sterile of any cultural material. Site 39LM6, a deeply buried, multicomponent village site at the mouth of Counselor Creek, 3 miles upstream from site 39LM238, was visited, and an eroding cache pit excavated. Some additional collecting was done, but no further excavation was attempted. The Neuman party terminated fieldwork on August 22, after 14 weeks in the field. The Neuman, Irving, and Deez parties shared camp facilities near the Brule Landing, 5 miles upstream from Old Fort Thompson.

A fourth River Basin Surveys field party in the Big Bend Reservoir area consisted of nine men, directed by Bernard Golden. This party conducted excavations at the Hickey Brothers site (39LM4), located on the right (west) side of the Missouri River, about 7 miles north of the Lower Brule Agency. The site is situated on the first terrace above the river, just north of the constricted neck of the Little Bend. The occupation area is delineated by a well-preserved fortification ditch. The latter is "coffin shaped" in plan, with bastions at the corners and in the intervening runs of wall. A single corner bastion was excavated, exposing a shallow moat backed by a pendulum loop of stockade posts. The stockade line was further verified along one of the long walls, and a series of 25 test pits was excavated to sample the body of the site. Four of the shallow "house" depressions within the fortification were tested by area excavation and trenching.

Results were limited. A relatively constant stratigraphy was revealed, but no aboriginal habitations were located with certainty. At least one hearth and other evidences of very localized "camp" areas were excavated, but artifacts were remarkably scarce. A limited number of potsherds (Stanley, Thomas Riggs) constitute the most distinctive material. A portion of the site had been disturbed by recent farming activities, but at best it does not seem to have been heavily occupied. This crew terminated fieldwork on August 20, after 10 weeks in the field.

The fifth River Basin Surveys field party in the Big Bend Reservoir area had a crew of 14 men under the leadership of Dr. Warren W. Caldwell. Work of this party consisted of excavations at two sites immediately to the south of the Hickey Brothers site, on the first terrace of the Missouri River. The major portion of the season was devoted to continuing excavations begun in the 1957 season at the Black Partizan site (39LM218), a large multicomponent earth-lodge village, situated one-fourth mile south of the Hickey Brothers site. Four houses within the fortification ditch were exposed. In addition, deep cross sections of the moat were cut at two places, and two extensive midden areas were sampled by trenching. Several differing house patterns were recovered. The most distinctive consisted of a small (18-foot diameter) square(?) house with rounded corners, large intramural cache pits, and a dearth of house posts. Thomas Riggs pottery was characteristic. Two circular houses were exposed, one 35 feet in diameter, the other 29 feet in diameter. The larger, containing many bone and stone-wedged post holes, overlay a large rectangular house. Associated cache pits are probably attributable to the latter structure rather than to the former. Braced rims and typical Thomas Riggs rims are both present. The smaller circular house was characterized by an abnormally large group of in-floor cache pits. The pottery sample is varied and much of it may predate the house.

The deep midden debris overlying much of the site contained pottery rim sherds with horizontal trailed or incised decoration. Beneath the midden, a series of large cache pits produced an abundance of Talking Crow pottery. The fortification ditch varies from 12 to 15 feet in width and from 4 to 6 feet in depth, and contains both water-deposited silt and midden fill. The latter normally contains cord-marked body sherds and a scattering of mammal bone.

At site 39M215, lying between the Black Partizan and the Hickey Brothers sites, only a single house was excavated. Site 39LM215 physically overlaps both of the latter sites. The two houses dug at 39LM218 in 1957 appear to be associated with it. The single structure excavated this year was characterized by Talking Crow

pottery and an abundance of sheet-copper fragments. This party broke camp and returned to the Lincoln headquarters on August 12, after 9 weeks in the field. The Caldwell and Golden parties shared a joint field camp, situated adjacent to the sites under excavation.

The practice of using joint field camps of two or three parties each has, in the past two seasons, proved very economical and efficient. Combining of activities and expenses of several parties and the consequent reduction in total quantity of field equipment, vehicles, number of cooks, and other expenses constitute a major saving. Having several archeologists in a single camp is of great help in discussions pertaining to excavation methods and general archeological interpretations.

During the winter months two very brief Missouri Basin project field parties were at work in the Missouri Basin. William N. Irving visited the Merritt Reservoir area and the nearby vicinity in north-central Nebraska from December 2 through December 7. This one-man party made extensive examinations of a number of the small Sandhills lakes for possible localities in which to collect fossil pollen. This was in connection with building a master pollen profile which will aid in interpreting the archeological sequences at sites in the Big Bend Reservoir and other reservoir areas in the central portion of the Missouri Basin. A second purpose of the trip was to determine whether recent construction activity in the Merritt Reservoir area was endangering any previously unknown archeological remains. The potentialities for collecting fossil pollen looked very favorable, but actual collecting had to await colder weather when the lakes would be frozen over. No new archeological material that would be disturbed by work within the Merritt Reservoir area was noted.

The second wintertime River Basin Surveys field party within the Missouri Basin consisted of William N. Irving and Lee G. Madison, who were in the field from January 19 through the 30th. This party was accompanied by Dr. Paul B. Sears, pollen specialist from Yale University, who kindly volunteered his services in order to assist in this important aspect of the salvage program. The group visited the vicinity of the Big Bend Reservoir area and collected an extensive series of pond-deposit samples for pollen analysis. Dr. Sears has kindly agreed to analyze these samples for fossil pollen, and in fact has already begun such analyses. At least one core sample has provided a long pollen sequence, and others look promising. If a master profile can be established from these and other samples, it will assist greatly in identifying the vegetations and climates of past ages. By superimposing the pollen samples from archeological sites excavated in the Big Bend and other related reservoir areas upon this master pollen profile, climatic and ecological contexts can be determined for

these sites and the age of the sites thus be correlated with the climatic changes. Details of ecology are thereby added to the archeological records salvaged from the reservoir to provide a fuller picture of the prehistory of the area.

The 1959 summer field season in the Missouri Basin began in the Big Bend Reservoir area on June 4 with a single small crew, encamped near the Hickey Brothers site on the right bank of the Missouri River in Lyman County. Dr. Warren W. Caldwell and a crew of six began work on a series of sites at and near the proposed right (west) abutment of the Big Bend Dam, near the mouths of Good Soldier Creek and Counselor Creek. On Good Soldier Creek, site 39LM235 was found to have been largely destroyed by construction during the winter of several small boat-landing ramps, but test pits were excavated in the remaining portion of the site. Very little material was recovered. The nearby site, 39LM236, was found to be completely inundated by an unusually high water level in the Fort Randall Reservoir and no work was possible. At the mouth of Counselor Creek, the Useful Heart site (39LM6) was extensively trenched and full-scale excavation of this earth-lodge village site was in progress at the end of the year.

The only other Missouri Basin project party at work in June was a team of physical anthropologists consisting of William M. Bass, III, and two assistants. This team, working out of the Lincoln office, began operations on June 17 at the Department of Anthropology, University of Nebraska, making metric analyses of a large group of human skeletal remains from several reservoir areas in the Missouri Basin, and from other sites in the area. The team spent 5 days on a trip to the University of Oklahoma at Norman to make similar analyses, and at the end of the fiscal year was back in Lincoln studying the skeletal remains from sites in the Oahe Reservoir area. This party was materially assisted by a grant-in-aid to Bass from the University of Pennsylvania, Child Growth and Development Center, through the kindness of Dr. Wilton K. Krogman. This grant provided the salary for Bass and one assistant during June.

Cooperating institutions at work in the Missouri Basin at the beginning of the fiscal year included a party from the University of South Dakota, directed by Eugene B. Fugle, excavating at the Four Bears site (39DW2) in the Oahe Reservoir area; a party from the University of Idaho, directed by Dr. Alfred E. Bowers, excavating for the second season at the Rygh site (39CA4) in the Oahe Reservoir area; a joint party from the University of North Dakota and the State Historical Society of North Dakota, under the direction of Dr. James H. Howard, excavating at the Tony Glas site (32EM3) in the Oahe Reservoir area; a party from the University of Wyoming,

directed by Dr. William Mulloy, excavating at a series of sites in the Glendo Reservoir in Platte County, Wyo.; and a party from the University of Missouri, directed by Carl Chapman, in the Pomme de Terre Reservoir area of west-central Missouri. At the end of the fiscal year cooperating institutions were: A party from the University of Kansas, directed by Dr. Carlyle S. Smith, excavating at the Stricker Village site (39LM1) in the Big Bend Reservoir; a joint party from the University of North Dakota and the State Historical Society of North Dakota, directed by Dr. James H. Howard, excavating at the Huff site (32MO11) in the Oahe Reservoir area; and two parties from the University of Missouri, directed by Carl F. Chapman, excavating at a series of sites in the Pomme de Terre Reservoir and making preliminary surveys in the Kassinger Bluff Reservoir area of west-central Missouri. All these parties were operating through agreements with the National Park Service and were cooperating in the Smithsonian Institution research program.

During the time that the archeologists were not in the field, they were engaged in analyses of their materials and in laboratory and library research. They also prepared manuscripts of technical scientific reports and wrote articles and papers of a more popular nature.

The Missouri Basin Chronology Program, begun by the staff archeologists of the Missouri Basin project in January 1958, continued to function throughout the current year. This is a cooperative program, bringing together the enthusiastic support and wide range of experience of 34 individuals representing 20 research institutions working in the Missouri Basin area. This program, directed toward a more precise understanding of time sequences of the prehistoric cultures represented by the sites being excavated, is already beginning to be useful in more efficient planning of salvage operations. Concrete results are being realized with a minimum expenditure of time and funds. The program includes intensive research in dendrochronology, and in this phase the field crews have collected wood specimens to be used in developing two master charts, one for the lower Big Bend Reservoir area and one for the lower Oahe Reservoir area. Sufficient wood is now on hand to begin preparing the master charts into which archeological wood samples may later be fitted. In addition, plans are in progress for the services of a full-time dendrochronologist, working on other funds, to concentrate his efforts on this problem. Research in radioactive carbon-14 analyses is well underway within the framework of the program, and 11 specimens have been submitted to the University of Michigan Memorial-Phoenix Project Laboratory under the direction of Prof. H. R. Crane. Dates have been returned on all 11, and a second series of specimens is being prepared for submission. Pollen samples have been collected and are being analyzed by Dr. Paul B. Sears of Yale University.

Others have already been analyzed by Mrs. Catherine Clisby of Oberlin College, preparatory to establishing a fossil pollen sequence. Geologic-climatic investigations have been carried out by Alan H. Coogan, who was employed for the purpose by the River Basin Surveys. He worked in collaboration with William N. Irving in the lower Big Bend Reservoir area. Other less specific researches are in progress to bring all possible chronology techniques to bear on this one basic framework for Missouri Basin chronology.

The laboratory and office staff devoted its full time during the year to processing specimen materials for study, photographing specimens, preparing specimen records, and typing and filing of records and manuscript materials. The accomplishments of the laboratory and office staff are listed in the following tables:

TABLE 1.—*Specimens processed July 1, 1958, through June 30, 1959*

Reservoir	Number of sites	Catalog numbers assigned	Number of specimens processed
Big Bend.....	50	9, 254	71, 281
Dardanelle ¹	13	1, 975	4, 461
Fort Randall.....	4	21	512
Glendo.....	2	10	48
Lewis and Clark.....	1	7	158
Oahe.....	25	8, 668	80, 311
Sites not in reservoirs.....	3	48	194
Collections not assigned site numbers.	98	19, 983	156, 965
	5	17	83
	103	20, 000	157, 048

In the Arkansas Basin.

TABLE 2.—*Record materials processed July 1, 1958, through June 30, 1959*

Reflex copies of records.....	8, 968
Photographic negatives made.....	2, 792
Photographic prints made.....	11, 888
Photographic prints mounted and filed.....	5, 566
Plate layouts made for manuscripts.....	71
Transparencies mounted in glass.....	1, 108
Cartographic tracings and revisions.....	72
Color pictures taken in lab.....	434
Artifacts drawn.....	66
Lettering of plates.....	75
Profiles drawn.....	45

It is of especial interest to note that on January 22 the one-millionth specimen was processed by the Missouri Basin project laboratory. As of June 30, the Missouri Basin project had cataloged, in 13 years of

operation, a grand total of 1,074,418 specimens from 1,795 numbered sites and 54 collections not assigned site numbers, in 92 reservoir areas within the Missouri Basin. During the current fiscal year, 7 pottery vessels, 23 pottery vessel sections, and 1 stoneware bowl were restored, and 154 nonvessel artifacts were repaired. Archeological specimens from 3 sites in 2 reservoirs were transferred to the division of archeology, U.S. National Museum, and human skeletal remains from 26 sites in 8 reservoirs were transferred to the division of physical anthropology, U.S. National Museum. Archeological specimens (mostly trade goods) from three sites in one reservoir were transferred to the Region Two Office, National Park Service, for display at the Jefferson National Westward Expansion Memorial Museum in St. Louis, Mo. The Missouri Basin project received, by transfer, from the University of Kansas, through the courtesy of Dr. Carlyle S. Smith, sample rim sherds of the Campbell Creek Indented type from the Talking Crow site (39BF3), and sample rim sherds of three varieties of the Cadotte Collared type from the Two Teeth site (39BF204). These specimens have been added to the Missouri Basin project comparative collections.

On July 26-27, archeologists of the staff of the Missouri Basin project joined with archeologists of the National Park Service and of State agencies at work within the Missouri Basin in a roundtable field conference in Pierre, S. Dak. This session, called the 15½th Plains Conference, was devoted to basic technical problems arising from the current field activities, and such conferences are to become a regular feature each summer. During the Thanksgiving weekend, members of the staff participated in the 16th Plains Conference for Archeology, held in Lincoln. On April 17, members of the staff participated in the annual meeting of the Nebraska Academy of Sciences, also held in Lincoln. On April 30 and May 1 and 2, members of the staff attended and participated in the annual meeting of the Society for American Archaeology, held in Salt Lake City, Utah.

Dr. Robert L. Stephenson, chief, when not in charge of field parties, devoted most of his time to managing the office and laboratory in Lincoln and preparing plans and budgets for the 1959 summer field season. He spent a portion of his time working on a summary report of the Missouri Basin Salvage Program for the calendar years 1952-58 and on the preparation of a manuscript reporting the "Archeological Investigations in the Whitney Reservoir, Texas." He completely revised and submitted a manuscript, "Excavations at Pueblo Pardo, New Mexico," which he had prepared in collaboration with Joseph H. Toulouse, Jr., in 1941, for publication as a monograph of the School of American Research, Santa Fe, N. Mex. He prepared and submitted for publication by the Alice Ferguson Foundation of

Washington, D.C., a popular manuscript, "Prehistoric Peoples of Accokeek Creek." Throughout the year he served as chairman of the Missouri Basin Chronology Program. A photographic booklet, "The Inter-Agency Archaeological Salvage Program after Twelve Years," prepared by him at the end of last fiscal year, was published in September. In July he served as chairman of the 15½th Plains Conference held in Pierre, S. Dak. During the Thanksgiving weekend he attended and participated in the 16th Plains Conference for Archeology, serving as chairman for the half-day session on "Archeology of the Southern Plains," and presenting a paper on "The Sully Site" at another session. In January he attended and participated in the annual meeting of the Committee for the Recovery of Archaeological Remains, held in Washington, D.C. In April he attended the annual meeting of the Nebraska Academy of Sciences, presenting a paper on "Administration in Anthropology" which was published in abstract in the *Proceedings of the Nebraska Academy of Sciences*. On April 30 and May 1-2, he attended the annual meeting of the Society for American Archaeology and presented two papers, "River Basin Salvage Problems Today" and "The Missouri Basin Chronology Program," both of which were published in abstract in Abstracts of Papers of the 24th Annual Meeting of the Society for American Archaeology. During the year he gave eight talks on various aspects of Missouri Basin Salvage Archeology at five local organizations' regular meetings.

Dr. Warren W. Caldwell, archeologist, during the fall and winter months devoted most of his time to analyses of specimen materials recovered from sites he had excavated in the Dardanelle and Big Bend Reservoirs during the previous year. He completed all plates, figures, and manuscript text for the final report, "Archeological Investigations in the Dardanelle Reservoir of West-Central Arkansas." He prepared a brief technical report on "Firearms and Related Artifacts from Fort Atkinson, Nebraska" and another entitled "Comments on the 'English Pattern' Trade Rifles," both for publication in the *Missouri Archaeologist*. He prepared a manuscript, pictures, and captions for a photographic booklet entitled "Gavins Point Dam and the Lewis and Clark Lake" for publication by the Corps of Engineers, U.S. Department of the Army; and submitted for publication in the *Tree-Ring Journal*, an article entitled "Dendrochronology and the Missouri Basin Chronology Program." He prepared a statement on "Plains Archeology and the Salvage Program" for publication in the Encyclopaedia Britannica Yearbook. In addition, he prepared several mimeographed statements for distribution from the Missouri Basin project office, including "Report No. 3, Missouri Basin Project and Cooperating Institutions," and

"Statement No. 2, The Missouri Basin Chronology Program." His article "The Smithsonian Institution in Arkansas," prepared late last year, was published in the *Ozark Mountaineer* for July 1958. He prepared a book review of "Frontier Steel" by Arthur Rosebush, that was published in *Nebraska History* for March 1959. In July he attended and participated in the 15½th Plains Conference, held in Pierre, S. Dak. In November he attended the 16th Plains Conference for Archeology and served as chairman for the half-day session on "The Chronology Program" and presented a paper on "The Black Partizan Site" at another session. In April he served as the general chairman of the annual meeting of the anthropology section of the Nebraska Academy of Sciences, held in Lincoln, Nebr., and presented a paper entitled "Northwest Coast Archeology: An Interpretation," which was published in abstract in the *Proceedings of the Nebraska Academy of Sciences*. During the year he served as chairman of the dendrochronology section of the Chronology Program and gave a talk to the North Omaha Kiwanis Club on "The Missouri Basin Salvage Program."

Harold A. Huscher in July participated in the 15½th Plains Conference in Pierre, S. Dak., and in November attended the 16th Plains Conference for Archeology, where he served as chairman for the half-day session on "Field Reports" and presented two papers entitled "Mapping in the Fort Bennett Area" and "Chronologies from Ceramic Analysis." His other activities have been reported in a preceding section.

William M. Bass, III, temporary physical anthropologist, participated in the 15½th Plains Conference in July and after the completion of fieldwork, left the staff on September 2. During the spring months he devoted much of his own time to detailed metric analyses of the human skeletal remains excavated in the Oahe and other Missouri Basin reservoirs. On June 17 he returned to Lincoln to serve as party chief for the mobile physical anthropology team working in the general Missouri Basin area.

William N. Irving, archeologist, when not in the field directing excavations, was in the Lincoln office analyzing materials he excavated during the previous two summers, particularly in regard to the Medicine Crow site (39BF2) and the Aiken site (39BF215). In July he attended and participated in the 15½th Plains Conference at Pierre, S. Dak. On November 27-28 he attended the 16th Plains Conference for Archeology and presented two papers, "Pre-Ceramic Sites in the Big Bend Reservoir" and "Pre-Ceramic Chronology in the Big Bend Reservoir." In collaboration with Alan H. Coogan, he prepared a manuscript on "Late Pleistocene and Recent Missouri River Terraces in the Big Bend Reservoir, South

Dakota" to be published in the *Proceedings of the Iowa Academy of Sciences*. He was on leave without pay from February 9 to April 24, to complete work on a report on Arctic research previously done for Harvard University. On April 30 and May 1-2, he attended the annual meetings of the Society for American Archaeology. He served throughout the year as chairman of the geologic-climatic section of the Chronology Program. At the end of the year he was in the Lincoln office, continuing work on his report on investigations at the Medicine Crow and related sites.

James J. F. Deetz, temporary archeologist, participated in the 15½th Plains Conference held in July. He completed his fieldwork on September 5 and terminated his employment at that time. He spent a portion of his own time during the winter and spring months analyzing materials from, and preparing a report on, the ceramic components of the Medicine Crow site (39BF2).

Alan H. Coogan, temporary field assistant, participated in the 15½th Plains Conference held in July. He completed his fieldwork and terminated his employment on August 29. In November he participated in the 16th Plains Conference for Archeology held in Lincoln, Nebr., presenting a paper entitled "The Physical Basis for Chronology in the Big Bend Reservoir." During the fall and winter months, on his own time, he prepared the report in collaboration with William N. Irving for publication in the *Proceedings of the Iowa Academy of Sciences*.

Bernard Golden, temporary archeologist, completed his fieldwork and left the project on September 12. During the winter and spring months he devoted a portion of his own time to preparation of the first draft of a report on his 1958 excavations entitled "Excavations at the Hickey Brothers Site (39LM4), Big Bend Reservoir," which he submitted for review early in June. In July he participated in the 15½th Plains Conference held in Pierre.

Charles H. McNutt, archeologist, attended the 15½th Plains Conference in July. When not in the field conducting excavations, he devoted most of his time to analyses of materials he had excavated over the past 2 years and to preparation of reports. He served throughout the year as chairman of the carbon-14 section of the Chronology Program. On temporary-detached duty to the National Park Service from September 23 to November 15, for excavations at Fort Laramie National Monument, he completed a report on that work entitled "Excavations at Old Bedlam, Fort Laramie National Monument, 48G01, Wyoming, 1958." During the Thanksgiving weekend he participated in the 16th Plains Conference for Archeology, held in Lincoln, Nebr., and presented papers reporting on "Excavations in Fielder Bottom Area, Oahe Reservoir," "Exca-

vations at Fort Laramie National Monument," and "Radiocarbon Dating in the Missouri Basin Chronology Program." In April he prepared a paper for the Nebraska Academy of Sciences, entitled "Comments on Two Northern Plains Pottery Wares," published in abstract in the *Proceedings* of the Academy. From April 7 to June 14 he was on leave without pay to complete his doctoral dissertation, which was submitted to the University of Michigan on June 29. On April 30 and May 1-2, he participated in the annual meetings of the Society for American Archaeology, held in Salt Lake City, Utah, and presented a paper entitled "Can Paraffin Be Removed from Charcoal Samples?" in collaboration with Dr. John L. Champe of the University of Nebraska. It was published in abstract in the Abstracts of Papers of the 24th Annual Meeting of the Society for American Archaeology. During the year he also continued work on a manuscript on ceramic taxonomy of the South Dakota area and presented two slide talks to local civic groups concerning River Basin Salvage Archeology. He also wrote an article, "Bibliography of Primary Sources for Radiocarbon Dates," in collaboration with Richard P. Wheeler, which was published in *American Antiquity*, volume 24, No. 3. At the end of the year he was preparing to begin fieldwork in the Oahe Reservoir area early in the next fiscal year.

Robert W. Neuman, archeologist, in July participated in the 15½th Plains Conference held in Pierre. During the time he was not in the field conducting excavations he spent a large portion of his time in analyzing materials and preparing reports of excavations conducted the previous two summers. September 29-October 3 he made a trip in company with Harry E. Weakly, who kindly contributed his time, to the Big Bend and Oahe Reservoir areas to collect dendrochronological specimens. On November 27-28 he participated in the 16th Plains Conference for Archeology, presenting a paper on "Archeological Investigations in the Fort Thompson Area." From December 4 to 21 he was on temporary-detached duty with the National Park Service to conduct excavations at George Washington Carver National Monument. He submitted a final report on that work early in January. He prepared a report on "Representative Quill Flatteners from the Central United States," which was read in absentia at the Nebraska Academy of Sciences meeting in Lincoln on April 17, and which was published in abstract in the *Proceedings* of the Academy. From February 9 to June 29 he was transferred to the River Basin Surveys outside the Missouri Basin for work in the Chattahoochee River Basin. His activities there have been described in previous pages. At the end of the year he was back in the Lincoln office working on a report, nearing completion, on

excavations in a series of mound sites in the Big Bend Reservoir area.

G. Hubert Smith, archeologist, at the beginning of the fiscal year was on temporary-detached duty with the National Park Service, conducting excavations at Fort McHenry National Monument, in Baltimore, Md. He submitted a report on his findings in September. On October 1 he returned to duty with the Missouri Basin project and spent the period from then until February 9 compiling a comprehensive report on several seasons' work at Site 32ML2, Forts Berthold I and II, and Like-a-Fishhook Village. This report will combine the findings of five archeologists during four seasons of work at this site in the Garrison Reservoir of North Dakota. In addition there will be an ethnohistoric account of the site. In February he was transferred to the Chatahoochee Basin project where he remained until June 17, when he again returned to the Missouri Basin project. In November he attended the annual meetings of the American Indian Ethnohistorical Conference and the American Anthropological Association, held in Washington, D.C. At a symposium of the latter group he contributed a paper on "Interpretive Values of Archeological Evidence in Historical Research." During the year he had a previously written article entitled "Great Carrying Place" published in the *Naturalist*, a quarterly publication of the Natural History Society of Minnesota. He prepared reviews of "The Indians of Quetico," by Emerson S. Coatsworth, for publication in the fall 1958 issue of *Ethnohistory*, and of "New Light on Old Fort Snelling," by John M. Callender, for publication in a future issue of *Nebraska History*. He also prepared a brief article describing the work at Fort McHenry and submitted it for publication in the *Maryland Historical Magazine*. At the end of the year he was again at work on the comprehensive report on Site 39ML2, Forts Berthold I and II, and Like-a-Fishhook Village.

Richard P. Wheeler, archeologist, when he was not in the field, devoted his time to analyses of materials and preparation of reports on sites excavated by him in past years. He completed the final draft of his manuscript, "The Stutsman Focus: An Aboriginal Culture Complex in the Jamestown Reservoir Area, North Dakota." He also completed the major portion of a draft of a manuscript entitled "Mounds and Earthworks in the Jamestown Reservoir Area of North Dakota" and of another entitled "Three Stratified Occupation Sites in the Oahe Dam and Reservoir Area, South Dakota." In July he participated in the 15½th Plains Conference held in Pierre, and in November attended the 16th Plains Conference for Archeology, held in Lincoln, presenting papers on "Investigations near Old Fort Bennett, Oahe Reservoir" and "Dendrochronology in the Central North-

ern Plains," the latter in collaboration with Harry E. Weakly. In April he presented a paper at the Nebraska Academy of Sciences meeting entitled "Comments on 'Method and Theory in American Archeology,'" which was published in abstract in the *Proceedings* of the Academy. On April 30 and May 1-2, he participated in the annual meetings of the Society for American Archaeology in Salt Lake City, Utah, and presented a paper entitled "The Middle Prehistoric Period in the Central Plains," which was published in abstract in the Abstracts of Papers of the 24th Annual Meeting of the Society for American Archaeology. During the year he collaborated with Charles H. McNutt, as previously mentioned, in an article that was published in *American Antiquity*. On May 30 he terminated his employment with the Missouri Basin project and transferred to the National Park Service, joining the Wetherill Mesa project at Mesa Verde National Park.

COOPERATING INSTITUTIONS

A number of institutions and agencies cooperated in the Inter-Agency Salvage Program in several areas throughout the United States. In addition to those previously mentioned in the sections on the Missouri Basin and the State of Kansas, there were 19 working under agreements with the National Park Service. The University of Georgia continued its investigations at the Hartwell Reservoir on the Tugaloo River and conducted excavations in the Oliver and Walter F. George projects on the Chattahoochee River. The University of Kentucky made surveys and did some digging in the Barkley Reservoir area on the Cumberland River and the Nolin Reservoir Basin on the Nolin River. The New Jersey Museum did salvage work on Tock's Island, N.J. The University of Michigan carried on investigations along the Saginaw River in Michigan. The State University of Iowa did survey and test digging at the Rathbun project on the Chariton River in Iowa. The University of Oklahoma did some further work at Fort Gibson on the Grand River and at the Oolagah Reservoir on the Verdigris River. The University of Texas continued its operations in the Ferrell's Bridge area on Cypress Creek in eastern Texas and in the Diablo Reservoir region along the Rio Grande. Texas Western University also worked in the Diablo district. The School of American Research continued its studies in the Navaho Reservoir area along the San Juan River in northern New Mexico. The University of Utah and the Museum of Northern Arizona completed surveys in the Glen Canyon Reservoir area on the Upper Colorado River and started a series of excavations in a number of sites. The University of Utah completed its investigation of the Flaming Gorge project, also on the Upper Colorado. The University of Arizona conducted investigations along the Gila River above the Painted Rocks Reservoir area. In

California the University of Southern California completed a series of investigations at the Casitas Reservoir on Coyote Creek. The University of California at Los Angeles excavated a site in the Terminus Reservoir area on the Kaweah River. The University of California at Berkeley completed its excavations in the Trinity Reservoir Basin on the Trinity River, and San Francisco State College made studies at the Whiskeytown project on the Upper Sacramento River. The University of Oregon continued operations in the John Day Reservoir in the Columbia River. The University of Washington completed its investigations in the Priest Rapids Reservoir area, also in the Columbia River, and the State College of Washington continued its excavations in the Ice Harbor Reservoir area on the Snake River. A number of local groups and institutions continued to assist on a voluntary basis. These mainly were in New York State, Ohio, Indiana, Tennessee, and southern California.

ARCHIVES OF ETHNOLOGY

The Bureau archives continued during the year under the custody of Mrs. Margaret C. Blaker. On June 8 Nicholas S. Hopkins entered on duty as a summer intern to assist in arranging and describing manuscript collections, and on June 15 Winfield H. Arneson, summer intern, entered on duty to assist with photographic collections.

The use of the manuscript collections by anthropologists and historical researchers continues to increase. Approximately 329 manuscripts were consulted by 92 visitors to the archives, and an equal number were consulted by the archivist in preparing replies to 87 mail inquiries concerning the nature and extent of manuscript information on specific topics or tribes. There were 22 purchase orders for a total of 2,897 pages of manuscript reproductions. In the course of examination, new and more detailed descriptions of about 50 manuscripts were prepared for the catalog, and a number of descriptive lists of manuscripts were prepared for distribution.

An anonymous English-Arikara vocabulary in a homemade notebook of 48 pages, thought to have been recorded ca. 1869-74 by an associate or acquaintance of Washington Matthews, was donated by Dr. John A. Pope of Washington, D.C.

Scholars, publishers, and the general public have continued to draw heavily on the photographic collections of the Bureau as a source of illustration and documentation. There were a total of 504 written inquiries, purchase orders, and personal inquiries concerning photographs, and 1,208 prints were distributed through purchase, gift, or exchange. As in previous years, a number of lists describing photographs in the Bureau's collection were prepared for distribution.

One hundred such lists relating to specific tribes and subjects are now available.

The Bureau has been fortunate in receiving the cooperation of several collectors of photographs that have ethnological and historical value. Some of the collectors lent their pictures for copying, while others gave their prints to the Bureau, thus insuring their preservation and making them available to students.

An important collection of over 115 negatives of Seminole Indians made by Charles Barney Cory, Sr., in Florida in the period 1877-95 was lent by Mrs. Zelma Carolyn Cory of Homewood, Ill., and Charles Barney Cory of Madison, Ill., through Alan R. Sawyer of the Art Institute of Chicago. Enlarged prints from these negatives are on file for reference at the Bureau. In addition, a group of 28 original and postcard prints by various photographers, collected by Charles Barney Cory in Florida and in the West, and relating to the Seminole, Shoshoni, Bannock, Paiute, Dakota, and other western tribes, was lent by Mr. Sawyer for copying.

A collection of 65 photographs of Seminole Indians, made by William D. Boehmer, Dwight R. Gardin, and others, was lent for copying by William D. Boehmer, educational field agent, Seminole Indian Agency, Okeechobee, Fla.

A series of 21 negatives, prints, and postcard reproductions relating to the Seminole Indians, made and collected by the photographer, C. N. Dutton, in the first decade of the 20th century, was lent for copying by Louis Capron, West Palm Beach, Fla., together with 4 Seminole photographs made by Capron in the 1930's.

A collection of 115 prints of Indians of the Dakota, Chippewa, Winnebago, Paiute, Crow, Apache, and other tribes, made by commercial photographers in the latter half of the 19th century, was donated by G. Hubert Smith of Lincoln, Nebr. In addition, several early stereographs of Minnesota Indian subjects were lent by him for copying.

A microfilm of the South Dakota Historical Society's collection of about 400 photographic prints relating to Western Indian history and Indian wars, along with a transcript of the accompanying caption material, was made available to the Bureau, through the courtesy of James Tubbesing of Winchester, Va., who made the film. A reference set of enlarged prints has been made of about 130 subjects selected from the series because they supplement or document photographs already in the Bureau's collections.

A series of commercial photographs, including 17 by H. Buehmann, Tucson, Arizona Territory, relating to the Apache Indians, and 9 by J. N. Choate, Carlisle, Pa., showing students at the Indian School at Carlisle, was received by transfer from the Department of Civil History, Smithsonian Institution.

A group of commercial photographs of Indians—including six outdoor scenes made by F. A. Rinehart in 1900, relating to the Crow Indians and showing details of costume and horse gear—was received as a gift from Henry G. K. Tyrell of Baltimore, Md., in memory of his father, Henry Grattan Tyrell.

A reference set of 18 photographs of drawings by Charles-Alexandre Lesueur, showing Indians and archeological sites sketched by Lesueur in the lower Mississippi Valley in the period 1816-37, was purchased from the studio of Victor Genetier in Paris. The original drawings are owned by the Museum of Natural History, Havre, France.

Six portraits of the Creek chief Pleasant Porter, made at various dates from 1872 to 1905 and assembled by Ralph W. Goodwin of Cambridge, Mass., while writing a biography of the chief, were lent by Mr. Goodwin for copying. He also provided biographical and other background information on several photographs of Creek Indians in the Bureau collections.

While examining the collections of Pawnee photographs at the Bureau, Stephen G. Gover of Weatherford, Okla., a member of the Pawnee tribe, supplied notes on a number of the photographs, including pronunciations and translations of personal names. Mr. Gover also lent for copying a photograph of the Pawnee chief, Crooked Hand, and another of Dog Chief, son of Crooked Hand.

With the assistance of Cheyenne informants, Mrs. Margot Liberty of Birney, Mont., provided identifications and biographical notes for a number of portraits of Cheyenne Indians in the Bureau collections. Father Peter Powell of Chicago, Ill., also furnished notes of this kind.

The extensive collection of photographs of North American Indians transferred to the Bureau from the Library of Congress last year has been sorted and arranged by tribe or area, and is now available for reference.

ILLUSTRATIONS

E. G. Schumacher, staff artist, prepared original illustrations and examined and approved or redrew other illustrations for the various Bureau publications that were being edited for printing. Among the subjects worked on during the year were Kansas archeology and archeological investigations in British Guiana, Mohave ethnopsychiatry and suicide, historic sites archeology on the Upper Missouri, and historic trading posts in North and South Dakota. In addition, a variety of scientific and technical art work was completed for other branches of the Institution.

EDITORIAL WORK AND PUBLICATIONS

The Bureau's editorial work continued during the year under the immediate direction of Mrs. Eloise B. Edelen. There were issued one annual report and four bulletins, as follows:

Seventy-fifth Annual Report of the Bureau of American Ethnology, 1957-1958. ii+36 pp., 5 pls. 1959.

Bulletin 168. The Native Brotherhoods: Modern intertribal organizations on the Northwest coast, by Philip Drucker. iv+194 pp. 1958.

Bulletin 169. River Basin Surveys Papers Nos. 9-14, Frank H. H. Roberts, Jr., editor. ix+392 pp., 73 pls., 13 figs., 9 maps. 1958.

No. 9. Archeological investigations in the Heart Butte Reservoir area, North Dakota, by Paul L. Cooper.

No. 10. Archeological investigations at the Tuttle Creek Dam, Kansas, by Robert B. Cumming, Jr.

No. 11. The Spain site (39LM301), a winter village in Fort Randall Reservoir, South Dakota, by Carlyle S. Smith and Roger T. Grange, Jr.

No. 12. The Wilbanks site (9CK-5), Georgia, by William H. Sears.

No. 13. Historic sites in and around the Jim Woodruff Reservoir area, Florida-Georgia, by Mark F. Boyd.

No. 14. Six sites near the Chattahoochee River in the Jim Woodruff Reservoir area, Florida, by Ripley P. Bullen.

Bulletin 170. Excavations at La Venta, Tabasco, 1955, by Philip Drucker, Robert F. Heizer, and Robert J. Squier. With appendixes by Jonas E. Gullberg, Garniss H. Curtis, and A. Starker Leopold. viii+312 pp., 63 pls., 82 figs. 1959.

Bulletin 171. The North Alaskan Eskimo: A study in ecology and society, by Robert F. Spencer. vi+490 pp., 9 pls., 2 figs., 4 maps. 1959.

Publications distributed totaled 27,721, as compared with 28,131 for the fiscal year 1958.

COLLECTIONS

The following collections were made by staff members of the Bureau of American Ethnology or of the River Basin Surveys and transferred to the permanent collections of the Department of Anthropology, U.S. National Museum:

FROM BUREAU OF AMERICAN ETHNOLOGY

Acc. No.

224347. Archeological materials collected by Ralph S. Solecki, from Marshall County, W. Va., during December 1948 and January 1949.

FROM RIVER BASIN SURVEYS

222302. Indian skeletal material from the Lake Spring site, Columbia County, Ga., collected by Dr. Joseph R. Caldwell.

224546. Archeological material collected by Waldo R. Wedel, for the R.B.S., B.A.E., from Osage Reservoir, Stanley County, S. Dak., during 1951.

224549. Samples of rock, brick, burned-earth, etc., collected by Ralph S. Solecki, R.B.S., from Ross County, Ohio, on November 30, 1949.

MISCELLANEOUS

Dr. John P. Harrington, Dr. A. J. Waring, and Dr. M. W. Stirling continued as research associates of the Bureau. Dr. Stirling used the facilities of the Bureau laboratory in the preparation of final reports on collections made in previous years during field trips to Panama and Ecuador.

Dr. Wallace L. Chafe, scientific linguist, joined the staff on April 3, 1959. In addition to the two summer interns mentioned in the report of the archivist, the Bureau was fortunate in having the services of Norma L. Hackelman, another summer intern, who assisted with the preparation and checking of bibliographies to be included in the Bureau's most useful bibliography and information leaflet series. Owing to the limited staff and heavy workload, there were issued only two new bibliographies and one revised list for distribution to the public, as follows:

SIL-50, 2d rev., 9/58. Selected list of portraits of prominent Indians in the collections of the Bureau of American Ethnology. 3 pp.

SIL-174, 12/58. Selected references on the Indians of Southeastern North America. (State index, pp. 12-14; musical recordings, p. 14; museum exhibits, pp. 14-16.) 16 pp.

SIL-197, 11/58. Selected bibliography of maps relating to the American Indian. 4 pp.

There were 2,759 letters of inquiry about American Indians and related problems received in the Director's office alone during the year. Information was furnished by staff members in answer to many of the queries, and to others, information leaflets or other printed items were supplied. In addition to the printed bibliographies and information leaflets described above several such items were compiled on topics of a general or specific nature and typescript copies sent out in answer to the hundreds of requests for this information. Several manuscripts were read and appraised by staff members for colleagues and scientific organizations. Numerous specimens were identified for owners and data supplied on them.

Respectfully submitted.

FRANK H. H. ROBERTS, Jr., *Director.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the Astrophysical Observatory

SIR: I have the honor to submit the following report on the operations of the Smithsonian Astrophysical Observatory for the fiscal year ended June 30, 1959:

The Astrophysical Observatory includes two divisions: the Division of Astrophysical Research, for the study of solar and other types of energy impinging on the earth, and the Division of Radiation and Organisms, for the investigation of radiation as it relates directly or indirectly to biological problems. Shops maintained in Washington, for work in metals, woods, and optical electronics, prepare special equipment for both divisions, and a shop in Cambridge provides high-precision mechanical work. The field station at Table Mountain, Calif., carries out solar observations.

DIVISION OF ASTROPHYSICAL RESEARCH

The research carried on at the Observatory during the past year has produced gratifying results in the areas of solar astrophysics, upper atmosphere studies, meteoritical studies, and satellite science. Some long-term objectives have been reached. The resulting gains in knowledge and the development of advanced observational techniques have revealed fresh areas of research and established new goals.

The Observatory has continued to maintain close liaison with Harvard College Observatory, the Massachusetts Institute of Technology, and other research centers. This policy confers mutual benefits.

Solar astrophysics.—At the Table Mountain station Alfred G. Froiland, employing methods recently developed, has made progress in his attempts to determine, from the Smithsonian solar spectrobolograms, the amount of atmospheric ozone in a vertical path, both in the visible spectral range and in the infrared region. He continues his study of the quantity and quality of haze in the atmosphere. The availability of a datatron at the California Institute of Technology has broadened and simplified the scope of this work. These new techniques are expected to lead to a more accurate and consistent method of measurement. Already, they have provided evidence for the existence of other related effects of energy absorption in the upper atmosphere.

Dr. Max Krook has developed two methods for determining the structure of nongray stellar atmospheres. They provide, for the first

time, rapidly converging procedures for calculating the structure of model atmospheres for hot stars, with given chemical composition, effective temperature, and surface gravity. He has formulated a method for calculating the structure of shock fronts in completely ionized hydrogen and in the presence of magnetic fields. The calculations contribute to our understanding of the fundamental properties of ionized gases. Procedures were devised for translating a microscopically formulated problem of gas dynamics into an approximately equivalent continuum problem. This method applies particularly to cases in which the Knudsen number, K , is not very small. Dr. Krook continues to study various problems in the dynamics of gases and the kinetic theory of gases.

Dr. Charles A. Whitney has begun a study of atmospheric structure and its correlation with solar activity. This work involves empirical analyses of satellite and solar data as they relate to atmospheric physics. Dr. Whitney continued his study of gas dynamics in astrophysical contexts, to obtain a numerical solution of the nonadiabatic equations of motion for the solar atmosphere. The procedure involves integration of the equations of motion for a variety of conditions. This is the first critical investigation of the propagation of nonlinear and nonadiabatic waves in the solar atmosphere. It will provide a basis for the interpretation of high-resolution photographs of the solar disk obtained by balloon-mounted telescopes. A comparison between the adiabatic and nonadiabatic equations will have a direct bearing on the theory of stellar chromospheres. A program to provide a firm basis for the theory of stellar pulsation was initiated by Dr. Whitney in 1955. This fundamental problem of classical astrophysics requires a variety of procedures, primarily theoretical. With the help of Dr. John Cox, the development of machine methods for the solution of pertinent equations has made considerable progress.

Upper atmosphere.—Dr. Jacchia's research on the secular acceleration of artificial satellites enabled him to establish marked transient effects on the acceleration of Satellite 1958 Delta One, which coincided with the great magnetic storms of July and September 1958. Dr. Jacchia's study established that these variations in acceleration were not due to solar electromagnetic radiation but to solar corpuscular radiation. This novel result is of outstanding significance in the field of solar-terrestrial relationships.

Studying the orbital accelerations of Satellites 1958 Beta Two and 1958 Delta Two, Dr. Jacchia found that they show semiregular fluctuations with an average period of 29 days. Further study suggested that a semiperiodic variation in the solar radiation with the synodic period of rotation of the sun, 27 days, seemed a more probable cycle.

Dr. Theodore E. Sterne completed a study of the inferential

methods used in evaluating observational data. He developed new methods, based on celestial mechanics, for inferring the density of the upper atmosphere from the motions of artificial satellites, and derived a value much higher than previous estimates. At an altitude of 220 km the density was found to be about 4.0×10^{-13} gm/cm³, and at 368 km the value was about 1.4×10^{-14} gm/cm. These methods for developing satellite data have particular importance because the satellites provide our only reliable source of information about the upper atmosphere. This knowledge, in turn, will augment our understanding of solar-terrestrial relationships. Dr. Sterne has also studied the theories and the types of reasoning involved in cosmology, to evaluate the probable reliability of our knowledge of the universe and its origin, and to compare the relative merits of various observational approaches.

Dr. J. Allen Hynek and George J. Neilson began a series of balloon experiments in cooperation with Col. David G. Simons of the Aero Medical Field Laboratory at Holloman Air Force Base, the Winzen Laboratories of Minneapolis, and the Massachusetts Institute of Technology Instrumentation Laboratories. This program will determine the feasibility of using a stabilized platform system in balloons designed for high-altitude observations. Two types of experiments are planned: (1) Unmanned balloons will carry a radio-controlled stabilization system for stellar observations made at altitudes up to 50,000 feet. (2) Manned balloons will carry a different type of stabilization system, controlled by an observer and a navigator (U.S. Air Force pilot) riding in the balloon gondola. They will attempt to make stellar observations at altitudes up to 85,000 feet, and, eventually, from beyond the earth's atmosphere. Both stabilization systems have now been developed and built by the Massachusetts Institute of Technology Instrumentation Laboratories. Preliminary tests and preparations have been made. Two observers, Mr. Neilson and William White, have been checked for physical fitness for flights up to 80,000 feet. The first launching of the unmanned balloon has been fixed for the fall of 1959.

The Director and Robert J. Davis completed the design of a telescope for use in space. The instrument will include an optical system, a detecting device, circuits to amplify and modify the output signal of the detecting device, and the auxiliary circuits necessary to protect the instrument from the effects of direct sunlight. Fitted into a socket in a "stable platform" within a satellite, the telescope will obtain important astrophysical data. The chief goals at present include an ultraviolet survey of the sky in three wavelength regions, and spectroscopic studies of particular celestial objects. Completion of the project will require about 3 years.

Meteoritical studies.—Research in meteoritics has provided invaluable information on the relation between meteors and comets, and the origin of comets. The Director's analyses of data, based on his Icy Comet theory, have yielded more information on the nature and origin of comets, and possibly the origin of the solar system. Recent studies of micrometeorites in the earth's atmosphere indicate that heavier elements, of the meteoritic category, condensed early in the original gases responsible for the formation of the cometary system and probably the planets.

An electron probe microanalyzer, designed and developed by Dr. F. Behn Riggs, Jr., with Dr. Andrew R. Lang as consultant, for the study of meteorites, is expected to be in full operation in the fall. Electron probe microanalysis is one of the newest methods for chemical analysis. In addition to its use for point-to-point analysis of the metallic constituents of iron meteorites, the microanalyzer will permit study of the gross distribution of elements across the surface of a sectioned meteorite measuring up to ten inches across. The distribution of elements cannot be measured on such a scale by any other method.

The Director, Dr. Fireman, Dr. Frances W. Wright, Paul W. Hodge, Hai Chin Rhee, Kenneth Covey, and Adolph Esposito continued the program of collection and identification of micrometeoritic dust. Collections of atmospheric particulate matter were made by high-flying jet aircraft. A collector mounted on a B-52 by the Boeing Aircraft Co. and flown by them has provided 19 exposed filters usable for analysis. The filters have been examined optically under a high-powered microscope and particles of various descriptions have been identified and counted. Those particles which might be meteoritic have been listed for analysis; some have been used for chemical analysis; and the rest will be used in a general analysis of contamination problems. The analysis of micrometeoritic dust indicates that these particles are magnetic and have more or less normal densities; tests for copper and nickel by neutron activation revealed that the sensitivity for copper was somewhat better than the value 0.1 percent for 10μ particles. The Massachusetts Institute of Technology reactor and the counting equipment of the Observatory laboratory were used for the experiment. The development of new and improved types of dust collectors for high-altitude aircraft is a continuing part of this program. The most recent development is a cylindrical impactor.

Dr. John Wood has investigated the various types of silicate meteorites, particularly of chondrites. Analysis of thin sections of chondrites in polarized light with the petrographic microscope has shown that the petrographic characteristics of these meteorites do not

appear to support the existence of primary bodies which antedated the parent meteorite planets.

Under the supervision of Dr. Luigi G. Jacchia, the precise reduction and analysis of photographic meteor trails have shown that practically all the visual meteors are cometary in origin; fewer than 1 percent are interstellar in origin, and the contribution from asteroidal sources is probably not much greater.

Under the supervision of the Director, Robert Briggs is studying the distribution of interplanetary dust particles to measure the number of particles in various parts of the solar system.

Dr. Fireman completed measurements of helium 3 in the Grant, N. Mex., meteorite and has determined its original mass (E. L. Fireman, *Planetary and Space Science*, vol. 1, pp 66-70, 1959). The helium 3 contents ranged from 6.5×10^{-6} cm³/g to 5.1×10^{-6} cm³/g. The Grant meteorite apparently was a pear-shaped object in space, with a mass of approximately 880 kg; its loss of mass during its plunge through the earth's atmosphere was approximately 400 kg. Dr. Fireman continued his measurement of the tritium, helium 3, and argon 39 in three stone and seven iron meteorites (E. L. Fireman and J. De Felice, *Astron. Journ.* vol. 64, p. 127, 1959; also *Geochim. et Cosmochim. Acta*, in press). The argon-exposure age of these meteorites ranges from 10^7 years to 6×10^8 years. This exposure age has been interpreted in terms of space erosion (F. L. Whipple and E. L. Fireman, *Nature*, vol. 183, p. 1315, 1959) and leads to the value 1.5×10^{-7} cm/year, for the upper limit of total erosion on an iron surface in space.

Satellite-tracking program.—The network of 12 satellite-tracking stations, under the supervision of Dr. Hynek, has gathered photographic data on the positions of artificial satellites. These data have allowed precision determination of the orbits of satellites and have thus provided geophysical and geodetic information. Seven objects were tracked. A total of 2,902 successful observations and more than 6,000 photographs were obtained. Engineering studies were begun to improve both the Baker-Nunn camera and the timing system, to refine the photography of orbiting objects. The stations were manned by 38 observers.

The Baker-Nunn camera has produced results of inestimable scientific value. The cameras are able to photograph stars to magnitude 12.0 with an effective exposure time of 1 second. Tracking accuracy ranges between 1 percent and 5 percent. The ultimate limiting magnitude, established principally by the time required to record appreciable skyfog, is about 16.0. The Baker-Nunn cameras secured photographs of the Vanguard experimental sphere, 1958 Beta Two, at ranges beyond 2,400 miles. These cameras also obtained photographs of the carrier

rocket of the Vanguard sphere, 1958 Beta One. This tracking system has demonstrated its ability to acquire as many as three photographs of satellites per day over a long period of time, in spite of bad weather and mechanical breakdowns. This rate of photography exceeds the original expectation by about 50 percent.

The Moonwatch program, under the supervision of Leon Campbell, Jr., depends on 218 teams comprising 5,000 volunteer observers, in the United States and abroad. Worldwide interest in the program continues, as evidenced by requests for affiliation from groups in North and South America, Africa, England, Spain, and the Middle East. Since the program began, Moonwatch has communicated 9,825 observations to the Cambridge headquarters. Arthur S. Leonard, leader of the Sacramento, Calif., team obtained improved values for the orbital elements of Satellite 1958 Beta One, which was believed "lost." These values led to the recovery of the satellite, which was then photographed by the Smithsonian camera stations.

These unprecedented accomplishments of the satellite-tracking programs prompted the executive director of the International Geophysical Year to congratulate the Director of the Observatory and his staff, on behalf of the U.S. National Committee and the Earth Satellite Panel.

The computation and analysis of optical observations continued under the supervision of Richard Adams as chief and Dr. Whitney as scientific supervisor. Refinements of techniques and programming methods have yielded gratifying results.

The Cunningham integration methods for the machine programming of satellite orbits, together with Dr. Don A. Lautman's equations for the osculating elements, have greatly facilitated the handling of satellite data and the graphing of perturbations of the orbital elements. A limited variety of orbits can be studied at present; for an orbit similar to that of Satellite 1957 Alpha the methods show separately the perturbational effects of drag and of the earth's oblateness.

Drs. Jacchia and Kozai derived new values for the second and fourth order coefficients of the earth's gravitational potential.

Dr. George Veis has initiated a differential corrections program which is being used to revise the orbits of Satellite 1958 Alpha and to obtain accurate elements for all satellites, in particular for 1959 Alpha One and 1959 Beta One. This program has also produced an ephemeris for 1958 Delta Two, during the period September 1958 to May 1959.

Jack Slowey has developed a program which makes it possible for the Baker-Nunn cameras to photograph satellites successfully over a long arc. The preliminary results have yielded much valuable information, and the Slowey Long-Arc Ephemeris will greatly increase

the flexibility and area of accomplishment of the camera stations.

Dr. Yoshihide Kozai has developed a theory of orbit perturbations including effects due to the sun and the moon. The use of this theory has yielded three coefficients of the earth's gravitational potential.

Dr. Sterne advanced a general, analytical theory of the motions of satellites, which makes allowance for air resistance and the earth's equatorial bulge, leading to improved understanding of the shape of the earth.

Dr. Whitney, in cooperation with the Army Ballistic Missile Agency, is working on a program to derive the orientation of satellites from observations of the strength of radio emission. His study of the periodic effects of atmospheric drag on a satellite orbit is of basic importance to the tracking program.

Dr. Veis is preparing a star catalog in the form of punched cards. This catalog will have particular value in photo reduction.

George G. Barton and Richard S. Aikens are developing a program of electronic image conversion whereby artificial earth satellites may be tracked by photoelectric methods. This program will facilitate visual observation of orbiting objects.

The number of observations processed by the Computation and Analysis Center totals 43,752; predictions sent to optical tracking stations number 12,825.

A program has begun for the reduction of photographic observations of satellites by the tracking stations. Under the supervision of Dr. Karoly Lassovszky, two methods are employed: (1) The astrometric method allows the computation of the exact orbits of the satellites and the derivation of important data relating to the distribution of mass inside the earth, the form of the earth, the true value of distances on the surface of the earth, and the variation in density in the atmosphere. (2) The photometric analysis method makes it possible to study the tumbling of the satellites, the secular changes of brightness of satellites, and the deterioration of their surfaces by meteoritic pitting and cosmic rays.

Two types of measuring engines have been evaluated: the Van Biesbroeck goniometer and the two-screw Mann engine. The system best suited to our needs has proved to be the Mann engine. A work rate study has shown that it will be necessary to operate at least five Mann engines for 8 hours a day, in order to reduce the most significant data flowing in from the camera tracking stations. A staff of 30 to 50 persons will be required to operate these five measuring systems.

To date, of the 5,981 films received, 62 percent were successful. Examination of the successful films reveals that 36 percent are measurable. About 500 precisely determined positions are ready for publication, although the precise time data have yet to be obtained

in some cases. The determination of the phototime expressed in terms of atomic time is now in progress.

For a program involving the measurement of the earth's albedo, observations have been made of the brightness of the earthshine on the dark part of the moon's crescent disk. These data will make it possible to evaluate the percent of clear and of cloudy parts of the atmosphere which contribute to earthshine.

Under the supervision of Charles A. Peterson, the Communications Center's activity has increased proportionately with the number of objects launched. An average of 539,057 words per month is cleared through the center; most of these words (groups of five numerals or letters) represent satellite information received or sent throughout the world.

PUBLICATIONS

Numbers 1 to 5 of volume 3, Smithsonian Contributions to Astrophysics, were published during the year. The following papers by staff members of the Astrophysical Observatory appeared in various journals:

- DAVIS, R. J., McCROSKY, R. E., WHIPPLE, F. L., and WHITNEY, C. A. A plan for operating an astronomical telescope in an earth satellite. *Astron. Journ.*, vol. 64, p. 50, 1959.
- DAVIS, R. J., WHIPPLE, F. L., and WHITNEY, C. A. An astronomical telescope in space. *Astronaut. Sci. Rev.*, vol. 1, p. 9 et seq., 1959.
- FIREMAN, E. L. The distribution of helium-3 in the Grant meteorite and a determination of the original mass. *Planetary and Space Sci.*, vol. 1, pp. 66-70, 1959.
- FIREMAN, E. L., and DE FELICE, J. Argon-39 and tritium in meteorites. *Astron. Journ.*, vol. 64, p. 127, 1959.
- HAWKINS, G. S., and WHIPPLE, F. L. The width of meteor trails. *Astron. Journ.*, vol. 63, pp. 283-291, 1958.
- HENIZE, K. G. A new planetary nebula NGC 6164-65 (Cederblad 135a, b). *Astron. Journ.*, vol. 64, pp. 51-52, 1959.
- HYNEK, J. A., HENIZE, K. G., and WHIPPLE, F. L. Report on the precision optical tracking program for artificial earth satellites. *Astron. Journ.*, vol. 64, p. 52, 1959.
- JACCHIA, L. G. The final moments of Sputnik II. *Sky and Telescope*, vol. 17, pp. 561-562, 1958.
- . Two atmospheric effects in the orbital acceleration of artificial satellites. *Nature*, vol. 183, pp. 526-527, 1959.
- . Corpuscular radiation and the acceleration of artificial satellites. *Nature*, vol. 183, p. 1662, 1959.
- KROOK, M. Structure of stellar atmospheres II. *Astrophys. Journ.*, vol. 129, pp. 724-733, 1959.
- . Structure of shock fronts in ionized gases. *Ann. Phys.*, vol. 6, pp. 188-207, 1959.
- KROOK, M., and PECKER, J. C. Sur le calcul de modèles d'atmosphère en équilibre radiatif (cas non-gris). *Comptes Rendus Acad. Sci. Paris*, vol. 247, pp. 1177-1179, 1958.

- RINEHART, J. S. Meteorites, satellites, and ceramics. *Bull. Amer. Ceramic Soc.*, vol. 37, pp. 461-467, 1958.
- . Impact effects and tektites. *Geochim. et Cosmochim. Acta*, vol. 14, pp. 287-290, 1958.
- SCHILLING, G. F., and STERNE, T. E. Densities and temperatures of the upper atmosphere inferred from satellite observations. *Journ. Geophys. Res.*, vol. 64, pp. 1-4, 1959.
- SCHILLING, G. F., and WHITNEY, C. A. Derivation and analysis of atmospheric density from observations of Satellite 1958 Epsilon. *Planetary and Space Sci.*, vol. 1, pp. 136-145, 1959.
- STERNE, T. E. The gravitational orbit of a satellite of an oblate planet. *Astron. Journ.*, vol. 63, pp. 29-40, 1958.
- . Density of the upper atmosphere. *Science*, vol. 128, p. 420, 1958.
- . The effect of the rotation of a planetary atmosphere upon the orbit of a close satellite. *Astron. Journ.*, vol. 64, p. 64, 1959.
- . Note on R. R. Newton's paper, "Motion of a Satellite Around an Unsymmetrical Central Body." *Journ. Appl. Phys.*, vol. 30, p. 270, 1959.
- STERNE, T. E., and DIETER, N. The constancy of the solar constant. *Smithsonian Contr. Astrophys.*, vol. 3, pp. 9-21, 1958.
- WHIPPLE, F. L. The coming exploration of space. *Saturday Evening Post*, August 16, 1958.
- . Optical tracking of artificial satellites. *Science*, vol. 128, pp. 124-129, 1958.
- . Notes on comets, meteors, and planetary evolution. *Publ. Astron. Soc. Pacific*, vol. 70, pp. 485-488, 1958.
- . Man into space. In "Vistas in Astronautics," vol. 2, pp. 145-147, Pergamon Press, 1959.
- . On the lunar dust layer. In "Vistas in Astronautics," vol. 2, pp. 267-272, Pergamon Press, 1959.
- WHIPPLE, F. L., and FIREMAN, E. L. Calculation of erosion in space from the cosmic-ray exposure age of meteorites. *Nature*, vol. 183, p. 1315, 1959.
- WHIPPLE, F. L., and HAWKINS, G. S. Meteors. In *Handbuch der Physik*, vol. 52, pp. 519-564. Springer-Verlag, 1959.
- WHIPPLE, F. L., and HYNEK, J. A. The IGY satellite tracking program as a source of geodetic information. *Ann. Geophys.*, vol. 14, pp. 326-328, 1958.
- . The IGY optical satellite tracking program as a source of geodetic information. *Bull. Geod.*, No. 49, pp. 50-52, 1958.

The Special Reports of the Astrophysical Observatory continue to present the results of analyses of satellite data carried out by various staff members. The demand has grown so that at present more than 1,500 individual scientists and research institutions regularly receive them. Special Reports Nos. 14-27, issued during the year, contain the following papers:

- ADAMS, R. M., BRIGGS, R. E., and UPTON, E. K. L. Positions of Satellite 1957 Beta One during the first 100 revolutions. *Spec. Rep. No. 16*, pp. 1-22, July 25, 1958.
- ALBERT, R. G., and ADAMS, R. M. Catalogue of satellite observations for January and February, 1959. *Spec. Rep. No. 24*, pp. 1-47, Apr. 9, 1959.
- . Catalogue of satellite observations for March and April 1959. *Spec. Rep. No. 26*, pp. 1-51, May 21, 1959.

- BRIGGS, R. E., and SLOWEY, J. W. An iterative method of orbit determination from three observations of a nearby satellite. Spec. Rep. No. 27, pp. 1-8, June 30, 1959.
- BULLIS, E. P. Moonwatch catalogue, October, November, and December, 1958. Spec. Rep. No. 21, pp. 13-36, Feb. 27, 1959.
- BULLIS, E. P., and CAMPBELL, L., JR. Moonwatch catalogue, May through June, 1958. Spec. Rep. No. 14, pp. 1-21, July 15, 1958.
- . Moonwatch catalogue, July and August, 1958. Spec. Rep. No. 18, pp. 23-44, Oct. 4, 1958.
- . Moonwatch catalogue, September 1958. Spec. Rep. No. 20, pp. 19-46, Jan. 5, 1959.
- CLARKE, J. B. Technical parameters of Satellites 1958 Delta and 1958 Epsilon. Spec. Rep. No. 18, pp. 3-4, Oct. 4, 1958.
- DAVIS, R. J. Timing satellite observations. Spec. Rep. No. 14, pp. 26-31, July 15, 1958.
- . Progress report on the planning of an artificial satellite containing an astronomical telescope. Spec. Rep. No. 20, pp. 9-12, Jan. 5, 1959.
- HAWKINS, G. S. A satellite meteor trap. Spec. Rep. No. 19, pp. 6-8, Dec. 6, 1958.
- HENIZE, K. G. Status of the photographic satellite tracking system. Spec. Rep. No. 14, pp. 22-25, July 15, 1958.
- JACCHIA, L. G. The descent of Satellite 1957 Beta One. Spec. Rep. No. 15, pp. 1-13, July 20, 1958.
- . The earth's gravitational potential as derived from Satellites 1957 Beta One and 1958 Beta Two. Spec. Rep. No. 19, pp. 1-5, Dec. 6, 1958.
- . An empirical formula for satellite ephemerides near the end of their lifetime. Spec. Rep. No. 20, pp. 1-4, Jan. 5, 1959.
- . The diurnal effect in the orbital acceleration of Satellite 1957 Beta One. Spec. Rep. No. 20, pp. 5-8, Jan. 5, 1959.
- JACCHIA, L. G., and BRIGGS, R. E. Orbital acceleration of Satellite 1958 Beta Two. Spec. Rep. No. 18, pp. 9-12, Oct. 4, 1958.
- KOZAI, Y. The earth's gravitational potential derived from the motion of Satellite 1958 Beta Two. Spec. Rep. No. 22, pp. 1-6, Mar. 20, 1959.
- . On the effects of the sun and the moon upon the motion of a close earth satellite. Spec. Rep. No. 22, pp. 7-10, Mar. 20, 1959.
- LEONARD, A. S. Determination of the orbit of Satellite 1958 Beta One. Spec. Rep. No. 27, pp. 9-15, June 30, 1959.
- MCCROSKY, R. E. A suggested rocket experiment for determination of atmospheric densities and winds at extreme heights. Spec. Rep. No. 20, pp. 13-16, Jan. 5, 1959.
- PETERSON, C. M. Communications center of the optical satellite tracking program. Spec. Rep. No. 18, pp. 5-8, Oct. 4, 1958.
- SCHILLING, G. F., and WHITNEY, C. A. Atmospheric densities from Explorer IV. Spec. Rep. No. 18, pp. 13-22, Oct. 4, 1958.
- SCHILLING, G. F., WHITNEY, C. A., and FOLKART, B. M. Preliminary note on the mass-area ratios of Satellites 1958 Delta One and 1958 Delta Two. Spec. Rep. No. 14, pp. 32-34, July 15, 1958.
- TESKE, R. G. Positions of Satellite 1958 Alpha during the first 1,400 revolutions. Spec. Rep. No. 17, pp. 1-173, Sept. 5, 1958.
- VEIS, G. The orbit of Satellite 1958 Zeta. Spec. Rep. No. 23, pp. 1-80, Mar. 30, 1959.

WHITNEY, C. A. The structure of the high atmosphere. I. Linear models. Spec. Rep. No. 21, pp. 1-12, Feb. 27, 1959.

———. The structure of the high atmosphere. II. A conduction model. Spec. Rep. No. 25, pp. 1-6, Apr. 20, 1959.

WHITNEY, C. A., and VEIS, G. A flashing satellite for geodetic studies. Spec. Rep. No. 19, pp. 9-19, Dec. 6, 1958.

OTHER ACTIVITIES

The Director, Dr. Jacchia, and Dr. Hynek attended meetings and participated in discussions of the 10th General Assembly of the International Astronomical Union in Moscow, August 1958. They visited various scientific institutions in the USSR. The Director presided at a symposium on astronomy from balloons, rockets, and satellites.

The Director, Dr. Jacchia, and Dr. Hynek participated in the discussions of the Fifth Congress of the Comité Spécial de l'Année Géophysique Internationale (CSAGI) in Moscow. Dr. Jacchia presented his study of the descent of Satellite 1957 Beta One, and served on the subcommittees for Rockets and Satellites and for Ionospheric Research.

The Director attended the Ninth Congress of the International Astronautical Federation for 1958, in Amsterdam.

Dr. Riggs attended the meeting of the Meteoritical Society held at Winslow, Ariz., and at the nearby Barringer Crater.

Mr. Davis participated in the meetings of the Optical Society of America, October 1958.

Dr. Gerhard F. Schilling participated in the Conferences on Satellite Launching at the National Academy of Sciences and at the Pentagon, October 1958.

A Conference on Contemporary Geodesy was held in December 1958 under the sponsorship of the American Geophysical Union in cooperation with the Smithsonian Astrophysical Observatory and Harvard College Observatory. The Director and various members of the staff participated in the discussions.

Dr. Fireman gave a lecture, "Sampling the Solar System for Isotopes," in February 1959, at the American Museum of Natural History, New York.

Dr. Whitney presented papers, by invitation, to the American Meteorological Society, in Chicago, Ill.; to the American Rocket Society, in Cambridge, Mass.; and at a symposium held by the Rand Corporation, Santa Monica, Calif., in the spring of 1959.

The Director took part in a Space Symposium sponsored by the National Aeronautics and Space Administration, and the American Physical Society in April 1959.

Dr. Fireman attended a Conference on Meteors at the Karlinka Institute, Stockholm, Sweden, June 1959.

Dr. Whitney participated in the discussions of the International Conference of Information Processing of the UNESCO, in Paris. He also presented a paper at the Ninth International Colloquium of the Institut d'Astrophysique, in Liège, Belgium, June 1959.

Dr. Hynek and Mr. Neilson made preparations for carrying out the Smithsonian Astrophysical Observatory's expedition to Spain, to observe the occultation of the star Regulus by the planet Venus.

Members of the staff attended meetings and presented papers before the American Astronomical Society, the American Physical Society, the American Geophysical Union, the National Telemetering Conference, the American Meteorological Society, the Department of Defense, the International Association of Geodesy, the American Astronautical Society, the American Society of Photogrammetry, the Mellon Institute, and the American Philosophical Society.

Every member of the scientific staff has given lectures at schools, colleges, civic groups, and military organization assemblies on the subject of satellites and space science.

A conference of the chiefs of satellite tracking stations was held on June 15-29, 1959, at the training station in Las Cruces, N. Mex., at the Smithsonian Institution in Washington, D.C., and at the Observatory in Cambridge. This conference, which provided the first opportunity for the chief observers to discuss particular problems related to the operation of tracking stations, proved of great benefit to all who attended.

The Director was elected to the National Academy of Sciences in April 1959. He served as consultant to the U.S. Office of Naval Research, to the U.S. Air Weather Service on problems related to the space age, and to the National Aeronautics and Space Administration. He is chairman of the Technical Panel on Rocketry and member of the Technical Panel of the Earth Satellite Program of the International Geophysical Year; chairman of the Panel on the Atmosphere of the Scientific Advisory Board of the U.S. Air Force; president of Commission 22, Meteors, Zodiacal Light, and Analogous Problems, of the International Astronomical Union; member of the U.S. Rocket and Satellite Research Panel; member of the Committee on Meteorology of the National Academy of Sciences, National Research Council; member of Upper Atmosphere Committee in the Meteorology Section of the American Geophysical Union; member of the Committee on Cosmic and Terrestrial Relationships of the American Geophysical Union; member of the Committee on Atmospheric Sciences of the National Academy of Sciences, National Research Council; member of the Panel on Chemistry of Space and Exploration of Moon and Planets of the National Academy of Sciences, National Research Council Committee on Bio-Astronautics; member of Space

Sciences Working Group on Orbiting Astronomical Observatories, National Aeronautics and Space Administration; and member of Physics of the Atmosphere and Space Committee, American Rocket Society.

The Director is general editor of the Smithsonian Contributions to Astrophysics; and of the international publication Planetary and Space Physics.

CHANGES IN STAFF

Dr. John S. Rinehart accepted a professorship at the Colorado School of Mines, Golden, Colo. He left the Observatory during the summer of 1958.

Dr. Gerhard F. Schilling resigned from the Observatory upon his appointment as Chief, Astronomy and Astrophysics, National Aeronautics and Space Administration, March 1959.

Richard M. Adams, who had been on leave from Texas A. & M. College, resumed his duties there in June 1959.

As of June 30, 1959, there were 179 persons employed at the Observatory.

BUILDING AND EQUIPMENT

The Astrophysical Observatory occupies space in five separate buildings. Plans for the erection of a new building on the grounds of the Harvard College Observatory have been approved; construction is expected to begin during the fall of 1959.

DIVISION OF RADIATION AND ORGANISMS

The Division has been engaged in research into the biochemistry and biophysics of the photomorphogenic mechanism in plants as controlled by radiant energy. In general, the red portion of the spectrum induces growth reactions that can be nullified by subsequent exposure to the far-red part of the spectrum.

Normal green sunflower seedlings produce large quantities of chlorophyll when grown in red or blue light, while, under the same conditions, mutant yellow or white seedlings lose their ability to synthesize protochlorophyll and chlorophyll. Although some chlorophyll is formed initially in these mutants, it is destroyed under continued exposure to light. Investigation of the photomorphogenic mechanism as measured by hypocotyl inhibition indicated that the response was the same in yellow mutants and normal green seedlings, but 50 percent greater in the white mutants. The inference is that the yellow pigments may be active in a protective function.

Studies are continuing on the biochemical changes that occur during the development of the chloroplasts of higher plants. It has been shown in our laboratory that excised leaves of dark-grown seedlings, when incubated on water and in the dark for 18 hours, lose one-half

of their protochlorophyllide synthesizing ability. Adding certain carbohydrates at optimal concentration or leaving one cotyledon attached prevented the loss of synthesizing ability. When sucrose was supplied as a substrate, the determination of carbohydrates within the leaves revealed a marked increase in reducing sugars and starch, indicating a rapid utilization of the products of phosphorolysis of sucrose.

Determination of the specificity of carbohydrates causing a stimulation of pigment synthesis and of their rates of metabolic utilization revealed that, of a dozen or more sugars varying from 3 to 18 carbon atoms, glucose at a concentration of 0.20 to 0.25 mole was most effective. This was found both through direct measurement of protochlorophyllide synthesis and by manometric measurements of respiration on tissues supplied with various carbohydrates. Technics are being developed for the isolation of proplastids and the measurement of their subsequent photomorphogenic development into mature chloroplasts.

During the course of our investigation of light-induced developmental changes in plants, one of our reported observations was that the lag phase in chlorophyll synthesis in etiolated bean leaf tissue could be eliminated by pretreating the leaves with low irradiances of monochromatic red or blue energy. The study of the lag phase of chlorophyll synthesis has been continued, and it has been demonstrated that X-irradiation of 5-10 kiloroentgens can increase the lag phase in etiolated bean leaves. Subsequent exposure to 10 minutes of white light initiated recovery of the chlorophyll synthesizing mechanism. Experiments are in progress to ascertain whether the recovery is a red- or blue-sensitive reaction and whether nonionizing radiation can counteract the effect of ionizing radiation in chlorophyll synthesis.

Radiant energy in the spectral region of 710 to 820 $m\mu$ significantly increases the frequency of chromosomal aberrations when used as a supplement to X-irradiation. Biochemical studies are being pursued to investigate the mechanism of the effect of far-red (710-820 $m\mu$) on the rejoining of chromosomes.

Three new members of the research staff of the Division are: Dr. Edward C. Sisler, biochemist; Dr. Walter A. Shropshire, Jr., physicist; and Dr. Maurice M. Margulies, biochemist. Dr. Sisler comes to the Smithsonian Institution from Brookhaven National Laboratory where he was engaged in photosynthesis studies. Dr. Shropshire returns to the Division from the California Institute of Technology, where he worked on action and transmission spectra. Dr. Margulies was formerly at Johns Hopkins University, where he was investigating photosynthesis and the biochemistry of microorganisms.

In November 1958, the Research Corporation of New York granted funds to the Division for the installation of a radioisotopes laboratory and for construction of greenhouse facilities and control rooms. The installation of the radioisotopes laboratory is well underway, and it should be in operation in the near future. The greenhouse is expected to be completed by the fall of 1959.

PUBLICATIONS

MOH C. C., and WITHROW, R. B. Nonionizing radiant energy as an agent in altering the incidence of X-ray-induced chromatid aberrations. II. Reversal of the far-red potentiating effect in *Vicia* by red radiant energy. *Radiation Res.*, vol. 10, pp. 13-19, 1959.

SHROPSHIRE, WALTER A., JR., and WITHROW, ROBERT B. Action spectrum of phototropic tip-curvature of *Avena*. *Plant Physiol.*, vol. 33, pp. 360-365, 1958.

WITHROW, ROBERT B., and KLEIN, W. H. Action spectra and kinetics of photomorphogenesis. *Atti del 2° Congresso Internazionale di Fotobiologia* Edizioni Minerva Medica, pp. 443-451. Torino, Italia (1958).

Respectfully submitted.

F. L. WHIPPLE, *Director.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the National Collection of Fine Arts

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1959:

SMITHSONIAN ART COMMISSION

The 36th annual meeting of the Smithsonian Art Commission was held in the Regents Room of the Smithsonian Building on Tuesday, December 2, 1958. Members present were Paul Manship, chairman; Robert Woods Bliss, vice chairman; Leonard Carmichael, secretary; Gilmore D. Clarke, David E. Finley, Walter Hancock, Bartlett Hayes, Henry P. McIlhenny, Ogden M. Pleissner, Charles Sawyer, Stow Wengenroth, and Andrew Wyeth. Thomas M. Beggs, Director, National Collection of Fine Arts, was also present.

A resolution on the death of George Hewitt Myers, a member of the Commission from 1944 until his death on December 23, 1957, was unanimously adopted.

Dr. Finley, chairman, reported for the executive committee that, as a result of balloting by mail, the Commission recommended Wilmarth S. Lewis to fill the vacancy caused by the death of George Hewitt Myers.

The Commission recommended reappointment of Gilmore D. Clarke, Stow Wengenroth, and Andrew Wyeth for the usual 4-year period.

The following officers were reelected for the ensuing year: Paul Manship, chairman; Robert Woods Bliss, vice chairman; and Leonard Carmichael, secretary.

The following were reelected members of the executive committee for the ensuing year: David E. Finley, chairman; Robert Woods Bliss, Gilmore D. Clarke, and Archibald G. Wenley, with Paul Manship and Leonard Carmichael, *ex officio*.

A motion was passed that the Regents of the Smithsonian Institution be asked to appoint a committee to advise in the development of plans for adapting the Civil Service Commission Building, formerly the Old Patent Office Building, to the needs of a National Portrait Gallery, and to prepare legislation concerning such.

It was further resolved that the chairman of the Smithsonian Art Commission shall appoint from its membership a subcommittee, includ-

ing three artist members, two museum director members, and the Director of the National Collection of Fine Arts, to advise in the development of plans for the housing of the National Collection of Fine Arts in the Old Patent Office Building.

Mr. Beggs pointed out that during the past year preservation activities, temporary and traveling exhibitions, and information services have greatly increased, with no concomitant additions to the administrative staff.

The Commission recommended acceptance of the following objects:

Bronze, Dr. John Dewey, by Alexander Portnoff (1887-1949), for the National Portrait Gallery. Gift of Mrs. Alexander Portnoff.

Bronze plaque, Paul Wayland Bartlett, N.A. (1865-1925), by John Flanagan, N.A. (1865-1952). Gift of Mrs. Armistead Peter, Jr.

Eighteen bronzes and four medallions by Paul Wayland Bartlett, N.A. (1865-1925). Gift of Mrs. Armistead Peter, Jr.

Bronzes: Walter Griffin (1861-1935); Lafayette; Head of a Girl; Seated Torso; Standing Torso; Male Figure From Fountain; Male Figure From Fountain; Poetry; Philosophy; Rabbit; Rabbit; Eagle; Baby Robin; Cat; Pup; Goat; Lion; Two Teams of Horses. *Medallions:* Walt Whitman (1819-92); Woman Knitting; Georges Corneau; Primavera.

Oil, Fisherboys at Provincetown, by Charles Webster Hawthorne, N.A. (1872-1930). Gift of Walter Bachrach.

Oil, House in the Valley of Wyoming, by Henry Boese (1824-?). Gift of Cornelia Hill.

Oil, Paul Wayland Bartlett, N.A. (1865-1925), by Charles Sprague Pearce, A.N.A. (1851-1914), for the National Portrait Gallery. Gift of Mrs. Armistead Peter, Jr.

Three watercolors, Mammoth Hot Springs. Yellowstone: Canyon of the Yellowstone; and River-Pinnacle, by Thomas Moran, N.A. (1837-1926). Gift of Mrs. Armistead Peter, Jr.

Watercolor on ivory, A. Laurason, by Jean Francois Vallee (fl. 1785-1815). Gift of Miss Mary Taylor through Mrs. Helen T. Steinbarger.

THE CATHERINE WALDEN MYER FUND

The following miniature, watercolor on ivory, was acquired from the fund established through the bequest of the late Catherine Walden Myer:

113. Miriam Etting Myers (1787-1808), by Benjamin Trott (c. 1770-c. 1841), from Mrs. Lesley Ashburner, Washington, D.C.

WITHDRAWALS BY OWNERS

Two miniatures, watercolor on ivory, Martha "Patty" Custis and John Parke Custis, by Charles Willson Peale (1741-1827), lent January 29, 1934, were withdrawn for exhibition purposes by Mrs. W. Hunter deButts and Mrs. H. E. Ely, Jr., on April 26, 1959.

LOANS RETURNED

Two oils, High Cliff, Coast of Maine, by Winslow Homer, and Moonlight, by Albert P. Ryder, lent September 25, 1957, to the Car-

negie Institute, Pittsburgh, for inclusion in its traveling exhibition of American Classics of the 19th century, were returned July 2 and 3, 1958, respectively.

Oil, Street Shrine, by Jerome Myers, lent November 27, 1957, to the Municipal Court for the District of Columbia, was recalled July 3, 1958, for inclusion in the Ranger Centennial Exhibition.

Oil, Man in White, by Cecilia Beaux, lent February 28, 1958, to the White House, was recalled July 3, 1958, for inclusion in the Ranger Centennial Exhibition.

Oil, Fifth Lake, by Edgar Payne, lent December 30, 1957, to the Office of the Vice President was recalled July 8, 1958, for inclusion in the Ranger Centennial Exhibition.

Three oils, The Figurine, by William Paxton; New Year's Shooter, by George Luks; and Self Portrait, by Will H. Low, lent March 15, 1955, October 18, 1956, and February 14, 1957, respectively, to the Department of Justice, were recalled July 10, 1958, for inclusion in the Ranger Centennial Exhibition.

Two oils, Tohickon, by Daniel Garber, and The Rapids, by W. Elmer Schofield, lent August 23, 1955, to the Department of Defense were recalled July 15, 1958, for inclusion in the Ranger Centennial Exhibition.

Oil, Heavy Sea, by Paul Dougherty, lent January 20, 1958, to the White House, was recalled July 21, 1958, for inclusion in the Ranger Centennial Exhibition.

Two sculptures, Manifest Destiny and Grizzly Bear, by Edward Kemeys, lent February 14, 1957, to the Department of Justice, were returned September 26, 1958.

Oil, George Washington, attributed to William Winstanley, lent May 13, 1955, to the Department of State, was recalled October 14, 1958, for inclusion in the exhibition "Profiles of the Times of James Monroe," October 26 to November 23, 1958.

Oil, The Island, by Edward W. Redfield, lent January 3, 1957, to the Corcoran Gallery of Art for their 25th Biennial Exhibition of Contemporary American Oil Paintings and circulated by the American Federation of Arts, was returned October 16, 1958.

Oil, Beach of Bass Rocks, Gloucester, Massachusetts, by Frank Knox Morton Rehn, lent November 6, 1957, to the office of Representative Richard Wigglesworth, was returned December 8, 1958.

Oil, Laguna, New Mexico, by Albert Lorey Groll, lent April 15, 1954, to the U.S. Court of Military Appeals, was returned March 11, 1959.

Two oils, Flume, Opalescent River, by Alexander Wyant, lent January 30, 1958, to the U.S. Court of Military Appeals, and Round Hill Road, by John Henry Twachtman, lent November 7, 1957, to the Municipal Court of Appeals, were recalled April 7, 1959, for the

exhibition "Turn-of-the-Century Paintings from the William T. Evans Collection," April 23 to June 1, 1959.

Oil, *The Bathers*, by Robert Reid, lent November 7, 1957, to the Municipal Court of Appeals, was returned April 7, 1959.

Three oils, *South Strand*, by Emil Carlsen, lent September 21, 1956, to the Bureau of the Budget; *End of Winter*, by John Henry Twachtman, lent January 22, 1957, to the Department of State; and *Idle Hours*, by Harry Mowbray, lent November 6, 1956, to the Interstate Commerce Commission, were recalled April 8, 1959, for the exhibition "Turn-of-the-Century Paintings from the William T. Evans Collection."

ART WORKS LENT

The following art works, oil paintings on canvas unless otherwise noted, were lent for varying periods:

To the Bureau of the Budget, Washington, D.C.:

February 13, 1959----- *Abraham Lincoln*, by George Story.

To the Carnegie Institute, Pittsburgh, Pa., for their International Retrospective Exhibition, December 4, 1958, through February 8, 1959:

September 15, 1958----- *Moonlight*, by Albert P. Ryder. (Returned February 13, 1959.)

To the Civil Service Commission, Washington, D.C.:

March 20, 1959----- *My Old Mill*, Holmescroft, near Rockville, by William H. Holmes (watercolor).

A Maryland Wheat Field, by William H. Holmes (watercolor).

Over the Maryland Fields, by William H. Holmes (watercolor).

The Normal Rock Creek about 1910, by William H. Holmes (watercolor).

To the Cosmos Club, Washington, D.C.:

October 29, 1958----- *Major John Wesley Powell*, by Henry Ulke. (Returned November 4, 1958.)

November 14, 1958----- *Major John Wesley Powell*, by Edmund Clarence Messer. (Returned December 8, 1958.)

To the Department of Defense, Washington, D.C.:

July 15, 1958----- *Sunset*, Navarro Ridge, California Coast, by Ralph A. Blakelock. (Returned August 13, 1958.)

August 13, 1958----- *In the Orchard*, by Edmund C. Tarbell.

To the Federal Communications Commission, Washington, D.C.:

May 5, 1959----- *Lauhala*, by Huc M. Luquiens (drypoint).

Derelict, by Beatrice S. Levy (aquatint).

Winter Moonlight, by George Jo Mess (aqua-tint).

In the Assiniboine Country, by R. H. Palenske (drypoint).

A Mallard Marsh, by Roland Clark (drypoint).

Spring Blossoms, Magnolia, by Bertha E. Jaques (drypoint).

Anemones, by Bertha E. Jaques (drypoint).

Canada Thistle, by Bertha E. Jaques (etching.)

Madonna Lilies, by Bertha E. Jaques (drypoint).

To the Department of History, U.S. National Museum, for an exhibition of the Cyrus W. Field Collection commemorating the centennial anniversary of the laying of the Atlantic Cable:

October 8, 1958----- First messages sent over the Atlantic Cable (original message from Queen Victoria and copy of President Buchanan's reply). (Returned October 31, 1958.)

To the Department of Justice, Washington, D.C.:

July 10, 1958----- Mrs. Joseph B. Collins, by G. P. A. Healy.
Coal Barge, Capri, 1880, by William H. Holmes (watercolor).

Miss Mildred Lee, by S. Seymour Thomas.

To the Knoedler Galleries, New York City, for an exhibition of the works of Raphaelle Peale, March 2 through 31, 1959, following the exhibition at the Milwaukee Art Center:

February 1959----- Robert Oliphant, by Raphaelle Peale (miniature, watercolor on ivory).

Rubens Peale, by Raphaelle Peale (miniature, watercolor on ivory).

(Both returned April 20, 1959.)

To the Lincoln Sesquicentennial Commission, Washington, D.C.:

February 11, 1959----- Abraham Lincoln, by George Story. (Returned February 13, 1959.)

To the Metropolitan Museum of Art, New York City, for an exhibition of the works of Winslow Homer, January 27 through March 8, 1959, following the exhibition at the National Gallery of Art:

January 15, 1959----- The Visit of the Mistress, by Winslow Homer.
High Cliff, Coast of Maine, by Winslow Homer.
(Both returned April 3, 1959.)

To the U.S. Court of Military Appeals, Washington, D.C.:

June 16, 1959----- Westward the Course of Empire Takes Its Way, by Emanuel Leutze. (Recalled July 13, 1959, to be sent to the American National Exhibition in Moscow.)

To the Milwaukee Art Center, Milwaukee, Wis., for an exhibition of works by Raphaelle Peale, January 15 through February 15, 1959:

December 24, 1958----- Robert Oliphant, by Raphaelle Peale (miniature, watercolor on ivory).

Rubens Peale, by Raphaelle Peale (miniature, watercolor on ivory).

(Both forwarded to Knoedler Galleries for an exhibition March 2 through 31, 1959.)

To the Municipal Court for the District of Columbia, Washington, D.C.:

July 3, 1958----- Twilight After Rain, by Norwood Hodge MacGilvary.

To the National Gallery of Art, Washington, D.C., for an exhibition of the works of Winslow Homer, November 23, 1958, to January 4, 1959:

July 16, 1958----- The Visit of the Mistress, by Winslow Homer.
High Cliff, Coast of Maine, by Winslow Homer.
(Both forwarded to the Metropolitan Museum of Art January 15, 1959, for exhibition.)

Senate Office Building, Washington, D.C.:

March 11, 1959----- Laguna, New Mexico, by Albert Lorey Groll.

To the Department of State, Washington, D.C.:

October 14, 1958----- Housatonic Valley, by Alexander Wyant.

December 31, 1958----- The Grindstone, by Charles W. Dahlgreen
(etching).

Horse and Wagon, Noon, by George Fawcett
(etching).

The Tramp, by Sears Gallagher (etching).

Sycamores by the River, by Alfred Hutt
(etching).

Fiesole from San Francisco, by Ernest Roth
(etching).

Locating the Blind, by Lee Sturges (etching).

Winter Cornfield, by Lee Sturges (etching).

The New Outfit, by Walter C. Yeomans (etching).

June 3, 1959----- Autumn at Arkville, by Alexander Wyant.

June 25, 1959----- End of Winter, by John H. Twachtman.

To the Department of the Treasury, Washington, D.C.:

March 3, 1959----- Portrait of a Lady, by Anders Zorn.

To the U.S. Information Agency, Washington, D.C., for the American National Exhibition in Moscow, July 25 through September 25, 1959:

June 15, 1959----- High Cliff, Coast of Maine, by Winslow Homer.

To the Veterans' Administration, Washington, D.C.:

December 16, 1958----- Schoolgirl, by Mlle. Marie Louise-Catherine
Breslau (charcoal drawing).

Nurse and Patient, by Jules Cayron (crayon
drawing).

"Ostend," by Arsene Chabanian (watercolor).

Before the Crucifix, by Louis Adolphe
Dechenaud (crayon drawing).

Homeless Victim of War, by Hubert-Denis
Etcheverry (crayon drawing).

"Saint Cloud, 4 Juin, 1906," by Francois Fla-
meng (watercolor).

Wounded Soldier, by Henri Gervex (pastel).

Peasant Girl, by P-Franc Lamy (watercolor).

Church Interior, by Maurice Lobre (charcoal
drawing).

"Primavera," by Edgard Henri Marie Maxence
(red chalk drawing).

"Les Poilus." "Quand je pense que j'aspirais
à la vie au grand air," by Louis Abel Tru-
chet (charcoal drawing).

"Pour que la liberté continue d'éclairer le
monde," by Henri Zo (charcoal drawing).

- February 16, 1959----- The First Sharps Rifle (Homer D. Jennings, St. Cloud, Florida), by Walter Beck (pastel).
 The Signal, After the Battle of Big Bethel (John Tregaskis), by Walter Beck (pastel).
 Fisher of the Fifth New York Volunteer Infantry, Duryee Zouaves, by Walter Beck (pastel).
 Drummer Boy of the Fighting Fifth after Gaines Mills (Robert F. Daly, New York City), by Walter Beck (pastel).
 The Lone Tree, by Arthur W. Hall (etching).
 Fry Street and the Old Polish Church, by Morris Henry Hobbs (etching).
 Mackerel, by Sears Gallagher (etching).
 Swift Current Falls, by Eugene Glaman (etching).
 Davy Jones' Locker, by Margaret Ann Gaug (etching).
 Homeward Bound, by Sears Gallagher (etching).
 The Port of Calvi, Corsica, by Philip H. Giddens (etching).
 Little Mexico, by Louis Oscar Griffith (etching).
 Top of Brooklyn Arch, by Allen Lewis (etching).
 Port of the Passing Ship, by Allen Philbrick (etching).
 The Great Tapestry Hall, Hampton Court Palace, by Leon R. Pescheret (etching).
 Middle Temple Hall, London, by Leon R. Pescheret (etching).
 Avenue of Flags, by Leon R. Pescheret (etching).
 Miao Feng T'a (near the Jade Fountain Pagoda), by Hans Luthmann (etching).
 Village Street, Bedford, Massachusetts, by Chester Leich (etching).
 Tree, Manhattan, by Martin Lewis (etching).
 Salem's Old Wharves, Massachusetts, by Philip Little (etching).
 Arch, Roman Forum, by Bertha E. Jaques (etching).
 Boat Shop, Venice, by Bertha E. Jaques (etching).
 Cheviot Sheep, Hampstead Heath, London, by Bertha E. Jaques (etching).
 Sphinx, Thames, London, by Bertha E. Jaques (etching).
 German Building, Chicago, by Bertha E. Jaques (etching).
 Seiners, Chioggia, by Bertha E. Jaques (etching).
 The Temple, by Bertha E. Jaques (etching).
 Artichoke, by Bertha E. Jaques (etching).

To the Office of Vice President Nixon, Washington, D.C.:

July 8, 1958----- Niagara, by George Inness. (Returned April 7, 1959.)

To The White House, Washington, D.C.:

July 11, 1958----- Portrait of J. J. Shannon, R.A., by Orlando Rouland.

July 21, 1958----- Southwesterly Gale, St. Ives, by Frederick Judd Waugh.

(Recalled April 8, 1959, for the exhibition, "Turn-of-the-Century Paintings From the William T. Evans Collection.")

August 19, 1958----- Lower Ausable Pond, by Homer Dodge Martin. (Returned October 27, 1958.)

December 17, 1958----- Male Wood Duck on Shallow Water, by Richard Meryman.

The Island, by Edward Willis Redfield.

Beach of Bass Rocks, Gloucester, Massachusetts, by Frank Knox Morton Rehn.

January 23, 1959----- Herbert Hoover, by Edmund Charles Tarbell.

March 6, 1959----- Westward the Course of Empire Takes Its Way, by Emanuel Leutze.

(Returned March 13, 1959.)

April 10, 1959----- Outskirts of the Woods, by David Cox. (Returned June 25, 1959.)

June 9, 1959----- Southwesterly Gale, St. Ives, by Frederick Judd Waugh.

June 25, 1959----- Sun and Storm, by Paul Dougherty.

SMITHSONIAN LENDING COLLECTION

Three oils, Little Paulus, Little Rosa, and Watching, by S. Seymour Thomas (1868-1956), gift of Mrs. Jean Haskell, were added December 2, 1958.

Bronze, Sun Dance, by Paul Wayland Bartlett, N.A. (1865-1925), gift of Mrs. Armistead Peter, Jr., was added December 2, 1958.

Fourteen paintings by Alice Pike Barney, lent November 2, 1955, to the Bio-Sciences Information Exchange were returned January 23, 1959, during a period of redecoration and re-lent, with Child with Fruit, March 18, 1959:

Minnete and Minet (pastel).

The Visitor (pastel).

Endymion.

The Dimple.

Little Girl (pastel).

Hail Fellow, Well Met (pastel).

An Oriental (pastel).

Fantasy (pastel).

Gladys (pastel).

Hippolyte Thom (pastel).

Laura in Hat (pastel).

Natalie in Greens (pastel).

Peggy (pastel).

Romance (pastel).

The following paintings were lent for varying periods:**To The White House, Washington, D.C.:**

December 17, 1958----- Ships at Anchor, Cherbourg No. 1, by Edwin Scott.

To the Department of the Treasury, Washington, D.C.:

March 3, 1959----- Shapes of Fear, by Maynard Dixon.

THE HENRY WARD RANGER FUND

The following paintings, purchased previously but not assigned, have been allocated to the institutions indicated:

<i>Title and artist</i>	<i>Assignment</i>
194. Circus Friends (watercolor), by A. Henry Nordhausen (1901-).	University of South Carolina, Columbia, S.C.
195. That Lonesome Road (watercolor), by Roy M. Mason (1886-).	San Joaquin Pioneer and Historical Society, Stockton, Calif.
205. Benares on the Ganges, by Maurice Sterne, N.A. (1877-1957).	Phillips Gallery, Washington, D.C.
206. Sea and Wharf at Provincetown, by Eric Isenburger, N.A. (1902-).	M. H. De Young Museum, San Francisco, Calif.
209. Everyday Is Washday (watercolor), by Frederic Whitaker, N.A. (1891-).	Henry Art Gallery, University of Washington, Seattle, Wash.
210. Philadelphia (watercolor), by Hugh Gumpel (1926-).	Art Institute of Zanesville, Zanesville, Ohio.

No. 25, Sleep, by Leon Kroll, N.A. (1884-), purchased by the Council of the National Academy of Design December 4, 1922, was reassigned by the Academy to the Fitchburg Art Museum, Fitchburg, Mass., on February 20, 1959.

According to a provision in the Ranger bequest, that paintings purchased by the Council of the National Academy of Design from the fund provided by the Henry Ward Ranger Bequest, and assigned to American art institutions, may be claimed during the 5-year period beginning 10 years after the death of the artist represented, the following painting was recalled for action of the Smithsonian Art Commission at its meeting December 2, 1958:

No. 68, Mlle. Maria Safonoff, by Irving R. Wiles, N.A. (1861-1948), returned to the Mount Holyoke College, Mount Holyoke, Mass., where it was originally assigned in 1928.

The following paintings, purchased by the Council of the National Academy of Design since the last report, have been assigned as follows:

<i>Title and artist</i>	<i>Assignment</i>
212. Boardwalk, by Carl Setterberg (1897-).	Columbus Museum of Arts & Crafts, Columbus, Ga.
213. The Critic (Kermit Lansner), by Aaron Shikler (1922-).	(Assignment pending.)
214. Yesterday and Before and Before, by Loring W. Coleman (1918-).	(Assignment pending.)
215. Night Road, Sheffield, by Joseph Barber (1915-).	Hollins College, Hollins, Va.
216. Autumn Landscape, by Robert Vickrey (1926-).	Pratt Institute, Brooklyn, N.Y.
217. The Painter, Shelley Fink, by David Levine (1926-).	(Assignment pending.)

<i>Title and artist</i>	<i>Assignment</i>
218. Practice, by Iver Rose (1899-).	E. B. Crocker Art Gallery, Sacramento, Calif.
219. Shopping District, by Sol Wilson (1896-).	Mary Washington College, University of Virginia, Fredericksburg, Va.
220. At Foot of Mount Teton (watercolor), by Chen Chi, A.N.A. (1912-).	Queens College Art Association, Flushing, N.Y.
221. Port City, by John Guerin (1889-).	J. B. Speed Art Museum, Louisville, Ky.
222. Harvest Time, Extremadura (watercolor), by Eileen Monaghan Whitaker, A.N.A. (1911-).	University of Massachusetts, Amherst, Mass.
223. Still Life (watercolor), by Avel de Knight (1923-).	Walker Art Center, Minneapolis, Minn.
224. Houses in Shade (watercolor), by Edwin L. Dahlberg (1901-).	Wesleyan University, Middletown, Conn.
225. Men and Mist (watercolor), by Irving Shapiro (-).	University of Vermont, Burlington, Vt.

SMITHSONIAN TRAVELING EXHIBITION SERVICE

In addition to 71 exhibits held over from previous years as listed below, 29 new shows were introduced. The total of 100 were circulated to 240 museums, one having been prepared for the U.S. Information Service's use abroad.

1954-1955: Japanese Woodcuts I; Design in Holland; and Carl Bodmer Paints the Indian Frontier.

1955-1956: Sargent Watercolors; Architectural Photography; Contemporary Finnish Architecture; European Glass Design; Two Finnish Craftsmen; Japan I by Werner Bischof; This is the American Earth; and Chinese Ivories from the Collection of Sir Victor Sassoon.

1956-1957: A Frenchman in America, Charles-Alexandre Lesueur; Paintings by Tessai; American Printmakers; George Bellows Prints and Drawings; Contemporary German Prints; Japanese Fish Prints; Architectural Photography II; German Architecture Today; Landscape Architecture Today; American Craftsmen, 1957; Recent Work by Harry Bertoia; Good Design in Switzerland; German Art Books; A World of Children's Books; Six Japanese Painters; Early American Woodcarving; Punch and Judy; Japan II by Werner Bischof; The World of Edward Weston; Young Germans Behind the Camera; and Swedish Rock Carvings.

1957-1958: American Primitive Paintings; Paintings by Jan Cox; Indian Paintings from Rajasthan; Mexican Work by Cock van Gent; Second Pacific Coast Biennial; The American City in the 19th Century; Recent American Prints; Early Prints and Drawings of California; Japanese Woodblock Prints; Theatrical Posters of the Gay Nineties; Birds by Emerson Tuttle; 100 Years of American Architecture; A Century of New England Architecture; Contemporary Portuguese Architecture; National Ceramic Exhibition, Sixth Miami Annual; Fulbright Designers; Nylon Rug Designs; Religious Banners; Twelve Scandinavian Designers; Swedish Textiles Today; Art Books from Italy; Books for Young Scientists; Burmese Embroideries; The Way of Chinese Landscape Painting; Japanese Dolls; Thai Painting; Paintings by Jamini Roy; The Anatomy of Nature; Photographs of Angkor Wat; Image of America; Pup, Cub and Kitten;

Photographs of Sarawak; Glimpses of Switzerland; Argentine Children as Illustrators; Art in Opera I—Tosca; Art in Opera II—Carmen; As I See Myself; The Four Seasons; and Children's Paintings from Morocco.

The exhibition American Folk Art was prepared for the use of the U.S. Information Agency in the Brussels Universal and International Exhibition.

UNITED STATES

Paintings and Drawings

<i>Title</i>	<i>Source</i>
Young British Painters-----	Arts Club of Chicago; Gimpel Fils, London; artists.
Dutch Master Drawings-----	Rijksmuseum, Amsterdam; Netherlands Embassy; museums and private lenders.
Fulbright Painters I-----	Institute of International Education; Senator J. William Fulbright; Lloyd Goodrich and artists.
Fulbright Painters II-----	
German Artists of Today-----	Dr. Kurt Martin; Kleemann Gallery; German Embassy.
Northwest Painters of Today--	Seattle Art Museum; Dr. Richard Fuller; artists.
Recent Work by Peter Takal--	Cleveland Museum of Art, Miss Leona E. Prasse; artists and collectors.
Transferences -----	Michael Chase, Zwemmer Gallery, London.

Graphic Arts

Advertising in 19th Century America.	Prints and Photographs Division of the Library of Congress.
The Engravings of Pieter Brueghel the Elder.	Mr. and Mrs. Jake Zeitlin, Los Angeles, Calif.
Three Danish Printmakers-----	Venice Biennale, 1958; Danish Embassy, Washington, D.C.; artists.
Great European Printmakers---	Munson-Williams-Proctor Institute, Utica, N.Y.
Charles Fenderich—Lithographer of American Statesmen.	Prints and Photographs Division of the Library of Congress.
Drawings from Latin America.	Visual Arts Section, Pan American Union, Washington, D.C.; artists; collectors.
Contemporary Religious Prints from the Sloniker Collection.	Mr. and Mrs. W. Ross Sloniker; Cincinnati Art Museum, Cincinnati, Ohio.
Religious Subjects in Modern Graphic Arts.	Pennell Collection, Library of Congress.
UNESCO Watercolor Reproductions.	UNESCO, Paris, France.

Design

British Artists-Craftsmen-----	British Artists-Craftsmen, Ltd.; artists.
Contemporary Finnish Rugs----	Bigelow-Sanford Carpet Co., Inc.; "Ornamo," the Finnish Crafts Guild; weavers.
Contemporary French Tapestries.	Association des Peintres-Corbonniers de Tapisseries, Paris; l'Association Française d'Action Artistique; French Ambassador; artists.
Contemporary Indian Crafts---	Bengal Home Industries Association, Calcutta, India.

Oriental Art

Stone Rubbings from Angkor Cultural Center of Angkor; Weyhe Gallery.
Wat.

Folk Art

Shaker Craftsmanship----- Index of American Design, National Gallery
of Art.

Photography

The Unguarded Moment, Pho- Peter Hunter, George Eastman House; Time
tographs by Erich Salomon. and Life Building, New York; Library of
Congress.

Children's Exhibitions

Children's Paintings from Yorkville Youth Council, Inc., N.Y.; Shankers
Southeast Asia. Weekly.

Drawings by European Chil- Dr. Joy B. Roy, collector.
dren.

Children's Paintings from In- Shankers Weekly; Fine Arts Commission's
dia. People to People Program.

A Child Looks at the Museum-- Junior School, Art Institute of Chicago.

Swiss Children's Paintings---- Mrs. Dorothy Snow, Boston Museum of Fine
Arts.

INFORMATION SERVICE AND STAFF ACTIVITIES

In addition to the many requests for information received by mail and telephone, inquiries made in person at the office numbered 2,016. In all, 199 works of art were submitted for examination and identification.

Special catalogs with introductions and biographical notes by the Director were published for the following three exhibitions: Profiles of the Time of James Monroe; Henry Ward Ranger Centennial Exhibition; and Turn-of-the-Century Paintings from the William T. Evans Collection. He also published a vignette, Francis Davis Millet, in the *Cosmos Club Bulletin* for May 1959.

Special catalogs were published for the following traveling exhibitions: American Primitive Paintings; British Artist-Craftsmen; Dutch Master Drawings; Contemporary French Tapestries; Fulbright Painters; Recent Work by Peter Takal; and UNESCO Water Color Reproductions. Special acknowledgments for two of these were written by Mrs. Annemarie H. Pope and Mrs. Jo Ann Sukel Lewis.

Mr. Beggs was one of the three jurors for the national newspaper cartoon contest on the subject of "Human Betterment," Birmingham, Ala., on January 16, 1959, and he judged the regional exhibition of the National League of American Pen Women on April 27, 1959. On September 1, 1958, he participated in a symposium, "The Study of Art as the Study of Man," at the American Psychological Association

meetings, and on May 10, 1959, in a television show, "The 25th Hour," concerning the history of miniatures, showing examples from the National Collection of Fine Arts permanent collection. He served on the Committee on Liturgical Arts of the Rock Spring Congregational Church, Arlington, Va., contributing three talks on the fine arts in a series of 12. He spoke on "Henry Ward Ranger, Painter and Benefactor," at the Art League of Manatee County, Bradenton, Fla., February 24, 1959. He became a member of the Committee for the Preservation of American Art, New York City, which awarded three heroic sculptures by Karl Bitter (1867-1915) to the city of Indianapolis in a national competition, and served for the third year on the Cultural Presentations Committee, Operations Coordinating Board, which advises the Department of State in the selection of artists for its oversea program.

On June 1-3, 1959, Mr. Beggs attended meetings of the International Institute for Conservation and the opening of the American Association of Museums meetings in Pittsburgh.

Mrs. Pope gave a talk on May 8 at the University of Virginia in Charlottesville on the Traveling Exhibition Service program. She attended openings of the Dutch Master Drawings in Washington, New York, Cleveland, and Chicago, and the meetings of the American Association of Museums in Pittsburgh. Miss Acton represented the Smithsonian Traveling Exhibition Service in a panel discussion at the meetings of the Southeast Museums Conference at Winston-Salem, N.C., between October 15 and 18, 1958.

The staff participated in the organization of three important special commemorative exhibitions in cooperation with other institutions. At the request of the James Monroe Memorial Foundation, a bicentennial exhibition was shown in the rotunda of the Natural History Building, a special brochure and catalog being published. An exhibition requested on behalf of the Lincoln Sesquicentennial Commission was organized, with the assistance of the Lincoln Museum, and shown at the Washington Cathedral. It was also exhibited in New York at the Sheraton Park Hotel in connection with the Independence Stamp Show. In cooperation with the National Academy of Design, a Henry Ward Ranger Centennial exhibition was shown in New York City during the fall, and circulated in part from January through June.

Rowland Lyon served as juror for the following four shows: Today's Artists in Charles County (Maryland); Westmoreland Hills Art Fair; Miniature Painters, Sculptors and Gravers Society of Washington, D.C.; and the Arts Club Outdoor Art Fair.

Twenty-seven paintings in oil on canvas from the permanent collections were cleaned and revarnished, 1 was relined, and 58 picture frames were repaired and refinished with the assistance of Buildings

Management Service. One painting, James W. Melville, by S. de Ivanowitz, was relined to repair a 16-inch tear in the canvas, for the U.S. National Museum.

Three paintings, Italian Landscape, Sunset Glow, by Tom Jones; Lord Roth, by Sir Joshua Reynolds; and Fishing Boats Beating Up to Windward, by Edward Moran, were renovated by Henri G. Courtais, who also restored The Cottage Door, by Thomas Gainsborough.

An oil, Major John Wesley Powell, by Edmund C. Messer, was renovated by Francis Sullivan.

Janice Hines relined two oil paintings, Major John Wesley Powell, by Henry Ulke, and House in the Valley of Wyoming, by Boese, and renovated the following from the William T. Evans Collection: The Blacksmith, by James Carroll Beckwith; The Black Orchid, by Frederick Stuart Church; The Spouting Whale, by William Morris Hunt; Algerian Water Carrier, by William Sartain; Water Lilies, by Walter Shirlaw; The Boy with the Arrow, by Douglas Volk; Mrs. William T. Evans and Son John, by Henry Oliver Walker; and A Gentlewoman, by J. Alden Weir.

Joseph Ternbach renovated the following 12 objects from the Gellatly collection: Incense burner, enameled and chased copper, 15th century (234.1); Byzantine necklace of gold medallions with inlaid depictions of Christ and Apostles (247.1); Champeve limoges plaque, the Crucifixion, French, 13th century (250.1); copper chasse, French, 13th century (251.1); Champeve limoges crucifix, French, 13th century (252.1); Champeve crozier, the Annunciation, French, 13th century (254.1); Russian ikon, Our Lady of Vladimir, (488.1); Pyxis with enamel decoration, 13th century (602.1); silver filigreed phoenix, Chinese (271.1); silver filigreed crown, ornamented with gems and symbols, Chinese (272.1); silver and enamel peacock (621.1); Chinese glass bowl (580).

Donald Hitchcock, Dumbarton Oaks Research Library, translated the Church Russian inscriptions on the silver-gilt ikon, Our Lady of Vladimir, in the Gellatly collection.

The entrance to the Benjamin H. Warder home, received from the Cooperating Committee on Architecture in May 1923, was dismantled, crated, and stored at Suitland on May 15, 1959.

An oil, John Tyler, by G. P. A. Healy, was copied by C. Gregory Stapko in a studio furnished to the National Collection of Fine Arts for that purpose through the courtesy of the National Gallery of Art.

SPECIAL EXHIBITIONS

Seventeen special exhibitions were held during the year:

August 27 through September 26, 1958.—Third Biennial Exhibition of Creative Crafts sponsored by the Ceramic Guild of Bethesda, Cherry Tree Textile Design-

ers, Clay Pigeons Ceramic Workshop, Designer-Weavers, the Potomac Craftsmen, and the Kiln Club of Washington, consisting of 142 items. Craft demonstrations were given. A catalog was privately printed.

October 12 through November 2, 1958.—Sculptures, Oils, Watercolors, and Drawings by Charles M. Russell, sponsored by the Montana State Society of Washington, D.C., consisting of 295 items. An illustrated catalog was privately printed.

October 26 through November 23, 1958.—Profiles of the Time of James Monroe, under the auspices of the James Monroe Memorial Foundation, consisting of 178 objects including paintings, sculpture, silhouettes, and memorabilia, was held in the rotunda. A catalog was printed.

December 3, 1958, through January 4, 1959.—The 21st Anniversary of the Metropolitan Art Exhibition, sponsored by the American Art League, consisting of 63 paintings and 12 sculptures, was held in the rotunda.

December 3, 1958, through January 4, 1959.—Henry Ward Ranger Centennial Exhibition consisting of 30 paintings from the National Collection of Fine Arts permanent collection that had been exhibited at the National Academy of Design, September 25 through October 12, 1958, in its commemoration of this artist's birth, was held in the rotunda. A catalog was printed.

Following the National Collection of Fine Arts showing, these 30 paintings were circulated from January through June 1959 to the following museums: Mint Museum of Art, Charlotte, N.C.; Art League of Manatee County, Bradenton, Fla.; Jacksonville Art Museum, Jacksonville, Fla.; Gibbes Art Gallery, Charleston, S.C.; and North Carolina Museum of Art, Raleigh, N.C.

January 10 through February 1, 1959.—British Artist-Craftsmen, sponsored by the Ambassador of Great Britain and Lady Caccia, and later circulated by the Smithsonian Traveling Exhibition Service, consisting of 178 objects, altar sculpture, stained glass, ceramics, glass, silver, etc. The Rose Book was lent by the Churchill family for special showing during this exhibition. A catalog was privately printed.

February 7 through 27, 1959.—The 66th Annual Exhibition of the Society of Washington Artists, consisting of 66 paintings and 18 sculptures. A catalog was privately printed.

February 28 through March 22, 1959.—Fulbright Painters and Designers, under the sponsorship of the Honorable J. W. Fulbright, Senator from Arkansas (circulated by the Smithsonian Traveling Exhibition Service), consisting of 60 paintings and approximately 200 objects, including furniture, textiles, silver, ceramics, stained glass, etc. A catalog was privately printed.

March 29 through April 26, 1959.—Contemporary Glass and Textiles by Lucrecia Moyano de Muniz, sponsored by the Ambassador of Argentina, Dr. César Barros Hurtado, consisting of 49 glass objects and 12 rugs.

March 29 through April 26, 1959.—Photographs of Argentina by Gustavo Thorlichen, sponsored by the Ambassador of Argentina, Dr. César Barros Hurtado, consisting of 58 prints.

April 19 through May 3, 1959.—Stone Rubbings from Angkor Wat (circulated by the Smithsonian Traveling Exhibition Service), consisting of 23 rubbings made from the 12th-century sandstone reliefs.

April 19 through May 3, 1959.—Photographs of Angkor Wat (circulated by the Smithsonian Traveling Exhibition Service), consisting of 100 photographs stressing architecture of monuments built by Khmer King, Suryavarman II.

April 23 through June 1, 1959.—Turn-of-the-Century Paintings from the William T. Evans Collection, consisting of 57 paintings exhibited for the 50th Anniversary American Federation of Arts Convention, was held in the first-floor galleries. A catalog was printed.

May 3 through 21, 1959.—The 26th Annual Exhibition of the Miniature Painters, Sculptors, and Gravers Society of Washington, D.C., consisting of 191 items. A catalog was privately printed.

May 3 through 21, 1959.—The 63d Annual National Exhibition of the Washington Water Color Club, consisting of 117 paintings. A catalog was privately printed.

June 2 through 9, 1959.—Children's Paintings from Morocco, a selection from the paintings owned by the Moroccan Embassy, consisting of 79 works.

June 14 through July 5, 1959.—Eighth Interservice Photography Contest, consisting of 75 photographs by members of the Armed Forces.

Respectfully submitted.

THOMAS M. BEGGS, *Director.*

Dr. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the Freer Gallery of Art

SIR: I have the honor to submit the 39th annual report on the Freer Gallery of Art, for the year ended June 30, 1959.

THE COLLECTIONS

Twenty-seven objects were added to the collections by purchase as follows:

GLASS

- 58.16. Syrian, early 14th century. Footed bowl with cover; gilding with red outlines and richly enameled with red, blue, green, white, and yellow colors forming floral and animal designs; much of it in Chinese style. Height 0.311 x diameter 0.210. (Illustrated.)

LACQUER

- 59.5. Indian, Deccani school, mid-17th century. Signed by Raḥīm Dekkānī; penbox (*qalamdān*) with figural scenes of the life of princes on both sides of the cover; arabesque and floral designs on brick-red outer side walls; gold floral pattern on the greenish-brown bottom and undecorated black interior; two metal chains at sides, and clasp. 0.282 x 0.053 x 0.049.

METALWORK

- 58.15. Indian, Mughal, 17th century (1605-27). Dagger with name of Jahāngir on upper chape. Steel blade with central ridge. Ivory flange inlaid with black mastic and gold wire (the hilt flange of walrus ivory is fixed to steel tang by pins ending in two silver rosettes); tang sheathed with gold and studded with 16 larger and 34 smaller jewels; guard and two chapes either in silver or niello or in reverse (chapes are now detachable); one larger, six smaller stones, and some gold inlay lost, one ivory corner chipped. Length (overall) 0.295 x width of guard 0.210.
- 58.6. Persian, Seljuq period, 11th century. Gold bracelet; quatrefoil hinge decoration composed of 4 large and 12 small domes with granulation work, and four inlaid turquoises. Diameter 0.106; weight 73.6 grams.
- 58.7. Persian, Sasanian period. Silver gilt plate; spherical, footless, with spread-eagle design in low, chased relief; framing wreath, double walls; part of gilt worn off; patination. 0.044 x 0.282.
- 58.14. Persian, Seljuq period, 11th-12th century. Gold bracelet, oval shaped; three rows of conical projections (66 in all), framed by two rows of smaller cones (172 in all); at the top side opening (closed by pin) 4 pairs of confronted dove figures partly executed with filigree, stand on 2 x 11 strands of twisted wire. Maximum diameter (overall) 0.097 x width 0.050; weight 334.5 grams.

PAINTING

- 58.8. Chinese, Ch'ing dynasty. Two mynah birds on a branch; a squirrel leaping for a wild grapevine; ink and light color on paper; by Hua Yen (1682-1758); artist's inscription and two of his seals on painting. 0.603 x 1.345.
- 58.9. Chinese, Ch'ing dynasty. Landscape, "A Morning View of the Yao Peak," by Chiang Shih-chieh (1647-1709); two inscriptions by the artist and nine of his seals on the painting; one collector's seal. 0.540 x 0.242.
- 58.10. Chinese, Ch'ing dynasty, 17th century. Landscape in ink and color on paper; by Hsiao Yün-ts'ung; inscription by the artist, signed and dated (1658); one seal of the artist. 0.410 x 0.957.
- 59.1- Indian, Sultanate period, middle or second half of 15th century. Set of
59.4. four miniatures from a manuscript of Amir Khusrav Dihlavi's *Khamse*; *nasta'liq* writing in four columns; painting in colors on paper. Average: 0.110 x 0.210.
- 58.4- Japanese, Ashikaga period, Idealistic Chinese school. A pair of 6-fold
58.5. screens painted in ink and color on paper; mountain landscape by Sesshu (1420-1506). Average: 1.610 x 3.512. (58.5 illustrated.)
- 58.11. Japanese, Kamakura period, Yamatoe school. "Yuzu Nembutsu Engi," dated 1329; in ink and color on paper. 0.290 x 14.163.
- 58.12. Japanese, Decorative school, 17th century. Wistaria and other flowers; by Roshū; ink and color on paper. 1.259 x 0.520.
- 58.17- Japanese, Ashikaga period, Yamatoe school, 15th century. Set of three;
58.19. landscape-Kumano Mandara; ink, color, and gold on silk. Average: 1.165 x 0.593.
- 59.8. Japanese, Momoyama, Ukiyoe school, mid-17th century. Scenes in Kyoto, "Gion Festival"; 6-fold screen; ink, color, and gold leaf on paper. 3.480 x 1.505.

POTTERY

- 58.13. Chinese, T'ang dynasty, *San-ts'ai* ware. Bowl with plain rim; clay: buff stoneware; transparent glaze, streaked with brownish-yellow and green; finely cracked; iridescent inside bottom. 0.047 x 0.103.
- 59.6 Chinese, Sung dynasty, *ting* ware. Vase of truncated bottle shape with flat base, rounded shoulders, short neck, and flaring lip; clay: fine-grained white stoneware; glaze: transparent, glossy; decoration: peony scrolls in brown slip with incised details. 0.163 x 0.166. (Illustrated.)
- 59.7 Chinese, Sung dynasty, celadon, Li-shui type. Covered vase with flaring foot ring; two loop handles; flaring mouth and vertical lip; clay: light-gray porcellaneous stoneware, fired reddish brown; glaze: transparent olive-green with fine crackle; decoration: incised on body, carved on cover. 0.370 (with cover) x 0.165.
- 59.9 Chinese, Ming dynasty, Hsüan-te period. Bowl, deep with thick walls and flat, low foot ring; clay: fine white porcelain; glaze: transparent, faintly bluish inside and flocculent blue outside, none on base; decoration: incised in the paste outside are waves, dragons, and lotus panels; 6-character mark of the period inside bottom. 0.125 x 0.264.
- 58.3 Japanese, Edo period, Kakiemon, early 18th century. Octagonal dish: clay: fine white porcelain; glaze: transparent, very slightly mat; decoration: two large fish in underglaze blue among water weeds in overglaze enamels. 0.050 x 0.333.

59.10 Japanese, Edo period, Nabeshima. Shallow dish with high, thin foot ring; clay: fine white porcelain; glaze: transparent; decoration: in underglaze blue outside and in, the latter combined with overglaze enamels. 0.037 x 0.150.

REPAIRS TO THE COLLECTIONS

Twenty-nine Chinese, Japanese, and Persian objects were restored, repaired, or remounted by T. Sugiura. In addition, he repaired 13 books for the library.

CHANGES IN EXHIBITIONS

Changes in exhibitions amounted to 445 as follows:

American art:		Paintings -----	60
Drawings -----	29	Stone sculpture-----	10
Etchings -----	20	Japanese art: Paintings--	4
Lithographs -----	18	Korean art:	
Chinese art:		Bronze -----	6
Bronze -----	34	Jade -----	7
Ivory -----	8	Metalwork -----	6
Lacquer -----	4	Pottery -----	65
Christian art:		Near Eastern art:	
Crystal -----	1	Bookbindings -----	10
Glass -----	3	Manuscripts -----	28
Gold -----	9	Metalwork -----	30
Paintings -----	8	Paintings -----	44
Stone sculpture-----	1	Pottery -----	18
Indian art:		Stone sculpture-----	2
Bronze -----	2	Wood sculpture-----	2
Manuscripts -----	12	Tibetan art: Paintings---	4

LIBRARY

Among the 1,005 acquisitions for the library of the Freer Gallery, there were 533 welcome gifts from individuals and exchanges from other institutions. Outstanding in the purchases were: *Dai kan wa jiten* (Great Chinese-Japanese dictionary), 10 of the 13 volumes have been received; *Sekai toji zenshu* (Catalogue of the world's ceramics) in 16 volumes, Tokyo, Kawade Shobo, 1955-58; *Sekai kokogaku taikei* (Archaeology of the world), to be complete in 16 volumes, Tokyo, Heibonsha, 1958-; Pearson, *Index Islamicus*, 1906-1955, Cambridge, Heffer & Sons, 1958; Kern Institute, *Annual bibliography of Indian archaeology*, vol. 16 (1948-1953), Leiden, Brill, 1958; Gulik, R. H. van, *Chinese pictorial art as viewed by the connoisseur*, Roma, 1958; Nishimura Tei, *Namban art, Christian art in Japan, 1549-1639*, Tokyo, 1959.

The library receives publications from mainland China and exchanges publications with the Hermitage Museum, Leningrad.

In all, 454 scholars and students other than the Gallery staff read and studied in the library. Twenty interested persons saw the Washington Manuscripts from the vault and studied the facsimiles.

In the reshelving of the library a rare book division was established. This includes these books which are outstanding examples of Japanese rare books: *Sanjūrok-kasen* (The thirty-six immortals of Japanese poetry), [n.p., Suminokura Soan, n.d.]. Each page contains a portrait with the name of the poet and his or her poem. These poets were selected by the poet Fujiwara no Kinto, with illustrations considered to be by Tosa Mitsushige. This is a perfect copy, probably in its original condition. Its slightly tinted papers of yellowish and brownish shades are interleaved with white papers. The sheets are not numbered and there is no other inscription except the names of the poets and their poems. The writings are judged to be in the style of Kōetsu's calligraphy. The second book is a collection: *Utai-bon* (one hundred *utai* for the Nō plays of Kanze school), first edition. Calligraphy by Honami Kōetsu with the 36 designs said to be by Sōtatsu, brother-in-law of Kōetsu. These are Saga-bon (books printed in Saga) under the patronage of Suminokura Soan, a very wealthy businessman and an ardent pupil of Kōetsu in calligraphy. The paper was probably prepared by "paper maker Kyōji," who lived with Kōetsu at his villa Takagamine. The papermill was situated by the river Kamiyagawa, which flows near Kōetsu's own villa at Takagamine. The books are printed from movable type on both sides of the paper. The sheets are folded once in the center, sewed with red silk, and bound two quires to a volume. The paper is white and colored, heavy, coated with clay, and printed with floral designs in mica. The covers are various-colored papers of the same quality, with dark-tan labels. 100 volumes in 6 lacquer boxes after Kōetsu's designs. Dr. Yukio Yashiro of Japan, an authority on these books, says the calligraphy on the boxes is not Kōetsu's. These volumes are extremely rare in Japan.

The year's record of cataloging included a total of 1,422 entries of which 666 analytics were made, 425 titles of books and pamphlets were cataloged, and 53 titles were recataloged and reclassified. Of the total of 4,970 cards necessary for the above work, only 610 were available as printed cards from the Library of Congress.

PUBLICATIONS

Two publications were issued by the Gallery as follows:

- The Freer Gallery of Art. 16 pp., 8 pls., 2 floor plans, 1 plan of court planting. Rev. ed. 1958. (Smithsonian Inst. Publ. 4185.)
- Fong, Wên. The lohans and a bridge to heaven. Occas. Pap., vol. 3, No. 1, 64 pp., 18 pls., 1 fig., 1958. (Smithsonian Inst. Publ. 4305.)

Papers by staff members appeared in outside publications as follows:

- CAHILL, JAMES F. Review of "The Arts of the Ming Dynasty." Catalog of an exhibition organized by the Arts Council of Great Britain and the Oriental Ceramic Society. *The Journal of Asian Studies*, Ann Arbor, vol. 18, No. 2, pp. 289-290, February 1959.
- . Foreword for the exhibition of paintings by Chi Chuan Wang held March 10-April 4, 1959, at Mi Chou Gallery, New York City.
- . Ch'ien Hsüan and his figure paintings. *Archives of the Chinese Art Society of America*, vol. 12, pp. 10-29, 1958.
- ETTINGHAUSEN, RICHARD. An exhibition of the ancient arts of Muslim countries in Lahore. *West Pakistan*, vol. 1, No. 8, April 1958.
- . Comments on the nature of Islamic art and its symbols. In *The Pakistan Quarterly*, vol. 8, No. 1, pp. 39-40, 64, Spring 1958.
- . 'Abbāsīdī-la pittura murale la miniature le arte decorative. *Enciclopedia Universale dell'Arte*, vol. 1, col. 10-18. Roma, Istituto per la Collaborazione Culturale, 1959.
- . 'Abdu's-Samad. In *Enciclopedia Universale dell'Arte*, vol. 1, col. 18-21. Roma, Istituto per la Collaborazione Culturale, 1959.
- . Review of "Der Orientalische Knüpfteppich, Versuch einer Darstellung seiner Geschichte," by K. Erdmann. *Oriens*, vol. 2, pp. 257-264, 1958.
- . Review of "Islamic Woodcarvers and their Works," by L. A. Mayer, for *The Muslim World*, Hartford (Conn.) Seminary Foundation, January 1959, p. 60.
- GETTENS, RUTHERFORD J. The identification of pigments and inerts on paintings and other museum objects. *Application of Science in Examination of Works of Art*, Sept. 15-18, 1958, pp. 31-49.
- . Examining tables in use at the Freer Gallery of Art. *Studies in Conservation*, vol. 4, pp. 23-27, illus., February 1959.
- POPE, JOHN ALEXANDER. Two Chinese porcelains in the Umezawa Collection. *Yamato Bunka No. 28*, pp. 1-12, December 1958.
- . Chinese characters in Brunei and Sarawak ceramics. *The Sarawak Museum Journal*, vol. 3, No. 11 (new series), pp. 267-272, 1958.
- STERN, HAROLD P. Ukiyoe paintings; selected problems. University of Michigan, 1958.
- WEST, ELISABETH HEBARD. A ring-mount for micro-cross-sections of paint and other materials. In *Studies in Conservation*, vol. 4, pp. 27-31, illus., February 1959.

PHOTOGRAPHIC LABORATORY AND SALES DESK

The photographic laboratory made 6,960 items during the year, as follows: 4,072 prints, 606 negatives, 1,894 color slides, 405 black-and-white slides, and 83 color film sheets. In all, 2,463 slides were lent during the year. At the sales desk 23,921 items were sold, comprising 2,098 publications and 21,823 reproductions (including postcards, slides, photographs, reproductions in the round, etc.).

BUILDING AND GROUNDS

The exterior walls of the building appear to be in good condition, but the roof has begun to show signs of wear. The exterior doors at

the north and south entrances were refinished to an antique bronze, and a brass handrail was installed at the north entrance. Window sills throughout the building have been painted, and painting of structural steel and metalwork in the attic was begun.

Four bookcases were completed for the library and one for the office of the Assistant Director, and work on exhibition cases for the galleries continued. A radial saw was installed in the cabinet shop, and a cabinet for a print dryer for the photographic laboratory and light-proof equipment for the technical laboratory were constructed. Gallery benches were redesigned and upholstered.

All trees, plants, and shrubs appear to be doing very well. The Meyer zoysia grass is making an excellent showing, except for two small plots on the south side that are in complete shade for the winter season. Experiments are being made to correct this situation. Vinca and Gomphrena planted around the fountain for the present season are doing very well.

ATTENDANCE

The Gallery was open to the public from 9 to 4:30 every day except Christmas Day. The total number of visitors to come in the main entrance was 119,333. The highest monthly attendance was in August, 14,891, and the lowest was in December, 4,018.

There were 2,508 visitors to the office for the following purposes:

For general information.....	1, 012
To submit objects for examination.....	470
To see staff members.....	193
To take photographs in court or exhibition galleries.....	127
To study in library.....	454
To see building and installations.....	37
To examine or borrow slides.....	41
To sketch in galleries.....	3
To see objects in storage:	
American art.....	23
Christian art (Washington MSS.).....	46
Far Eastern jade, lacquer, wood, ivory, etc.....	20
Far Eastern metalwork.....	28
Far Eastern paintings.....	183
Far Eastern pottery.....	35
Near Eastern bookbindings, glass, etc.....	7
Near Eastern metalwork.....	17
Near Eastern paintings.....	26
Near Eastern pottery.....	10

AUDITORIUM

The series of illustrated lectures was continued as follows:

1958

October 7.

Dr. Richard Ettinghausen, Curator of Near Eastern Art, Freer Gallery of Art. "Paintings of the Sultans and Emperors of India." Attendance, 296.

1958

- November 4. Basil Gray, Keeper of Oriental Antiquities, British Museum, London, England. "Five Hundred Years of Chinese Wall Painting at Tun-huang." Attendance, 293.

1959

- January 6. Dr. Wên Fong, Princeton University. "How to Look at Chinese Paintings." Attendance, 298.
- February 10. Miss Elizabeth Lyons, Queens College, New York City. "Temple Paintings of Thailand." Attendance, 234.
- March 10. Harold P. Stern, Associate Curator of Japanese Art, Freer Gallery of Art. "Popular Paintings of Tokugawa, Japan." Attendance, 157.
- April 7. Dr. John A. Pope, Assistant Director, Freer Gallery of Art. "Hinduism and Buddhism at Angkor." Attendance, 326.

Outside organizations used the auditorium as follows:

1958

- August 13. Ikebana International held a meeting during which Miss Seikoh Ogawa gave a demonstration and illustrated lecture on "Japanese Flower Arrangement." Attendance, 428.
- September 23-26. The U.S. Department of Agriculture, Marketing Workshop, held meetings with attendance as follows: 82, 96, 83, and 127; total, 388.

1959

- January 8-9. The U.S. Department of Agriculture, Federal Extension Service, held meetings with attendance as follows: 96 and 81; total, 177.
- January 13-20. The U.S. Department of Agriculture held all-day meetings of Administrative Conference (Telephone) with attendance as follows: 121 and 124; total, 245.
- January 27. The U.S. Department of Agriculture, Under Secretary's Office, held a meeting of the Farmers' Union. Attendance, 156.
- February 2. The District of Columbia Psychological Association held an evening meeting. Attendance, 62.
- February 19. The U.S. Department of Health, Education, and Welfare, Food and Drug Administration, held a seminar on "Metabolic Fate of Drugs in Different Species." Attendance, 167.
- April 2. The U.S. Department of Agriculture, Foreign Agricultural Service, showed a movie on Africa. Attendance, 153.
- April 14-
June 29. Twelve rehearsals were held by a group from the Smithsonian Institution for a musical program of 13th-century music using antique musical instruments.
- May 6. The U.S. Department of Health, Education, and Welfare, Food and Drug Administration, held an all-day meeting. Attendance, 82.
- May 20. The Smithsonian Institution sponsored an illustrated lecture by H. Alan Lloyd on "Pre-Renaissance Clocks and Their Influence." Attendance, 92.
- June 2. The Museum Store Managers held a meeting; cochairmen were Mrs. Elizabeth Ostertag, National Gallery of Art, and Mrs. Luor O. West, Freer Gallery of Art. A talk on "Copyright" was given by Richard MacCarteney, Copyright Division, Library of Congress. Attendance, 35.
- June 18. The U.S. Department of Agriculture, Food Extension Service, and The 4-H Club held a meeting. Attendance, 112.

1959

- June 24. American Library Association, Art Section, Chairman, Mrs. Bertha Usilton, librarian, Freer Gallery of Art, held a meeting. A talk was given on "A New Program in the Documentation of Art." Attendance, 220.
- June 30. The Smithsonian Institution, Division of Cultural History, presented "A Program of 15th-Century Music." Attendance, 361.

On October 8, 1958, the Gallery was open in the evening and docent service was given by Dr. James Cahill and Rutherford J. Gettens to a group of nine members of the Executive Committee, International Union of Pure and Applied Chemistry; Dr. Edward Wichers headed this distinguished group.

STAFF ACTIVITIES

The work of the staff members has been devoted to the study of new accessions, of objects contemplated for purchase, and of objects submitted for examination, as well as to individual research projects in the fields represented by the collections of Chinese, Japanese, Persian, Arabic, and Indian materials. Reports, oral and written, and exclusive of those made by the technical laboratory (listed below) were made on 8,637 objects as follows: For private individuals, 4,785; for dealers, 1,619; for other museums, 2,233. In all, 834 photographs were examined, and 1,151 Oriental language inscriptions were translated for outside individuals and institutions. By request, 20 groups totaling 430 persons met in the exhibition galleries for docent service by the staff members.

Five groups totaling 101 persons were given docent service by staff members in the storage rooms.

Among the visitors were 87 distinguished foreign scholars or persons holding official positions in their own countries who came here under the auspices of the State Department to study museum administration and practices in this country.

During the year the technical laboratory carried on the following activities:

Freer Gallery objects examined.....	115
Microchemically	2
Microscopically	36
Ultraviolet	30
X-ray diffraction.....	31
Chemical analysis.....	27
Treated, cleaned, or repaired.....	37
Outside objects examined.....	107
Microchemically	23
Microscopically	45
Ultraviolet	41
X-ray diffraction.....	4
Treated, cleaned, or repaired.....	6



58.16



59.6

Recent additions to the collections of the Frier Gallery of Art.



58.5

Recent addition to the collections of the Freer Gallery of Art

The following projects were undertaken by the laboratory during the year:

1. During February and March Mr. Gettens spent 2 weeks, and Miss West 6 weeks, working as guests in the Chemistry Department, Brookhaven National Laboratory, Upton, Long Island, N.Y. The project of spectrochemical analysis of some 30 inscribed ceremonial bronzes from the Freer collection, which was begun last year, was brought nearly to completion.

2. Chemical analysis of the same series of bronzes by conventional wet methods was completed.

3. Examination of some 550 jade objects in the Freer collection, which included X-ray diffraction analysis of 150 jades, was completed.

4. Mr. Gettens took over editorship of Abstracts of the Technical Literature and Archaeology and the Fine Arts, published by the International Institute for Conservation of Museum Objects, London, England.

5. The systematic collection of data on the technology of ancient copper and bronze in the Far East was continued.

6. Studies on the corrosion products of ancient metal objects were continued.

During the year, 4 written reports were made and 128 verbal reports given on objects examined in the technical laboratory.

By invitation the following lectures were given outside the Gallery by staff members (illustrated unless otherwise noted) :

1958

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| July 1. | Dr. Cahill, to the Society for Asian Art, San Francisco, Calif., "Painting Albums in China and Japan." Attendance, 100. |
| September 1. | Dr. Pope, at a session of the Division of Esthetics, Symposium of the American Psychological Association, Statler Hotel, Washington, D.C., "The Freer Gallery of Art." Attendance, 150. |
| September 3. | Dr. Cahill, at the Fourth Conference on Chinese Thought, Aspen, Colo., "Confucian Elements in Chinese Painting Theory." Attendance, 16. (Not illustrated.) |
| September 15. | Mr. Gettens, at the Seminar on Applications of Science in Examination of Works of Art, Museum of Fine Arts, Boston, Mass., "Identification of Pigments." Attendance, 73. |
| November 3. | Dr. Ettinghausen, at the Walters Art Gallery, Baltimore, Md., "Islam." Attendance, 183. |
| December 11. | Dr. Cahill, at the University of Chicago, Chicago, Ill., "Two Concepts of Painting in China." Attendance, 50. |
| December 12. | Dr. Cahill, at the University of Chicago, Chicago, Ill., "The Theory of Literati Painting." Attendance, 60. |
| December 14. | Mr. Stern, at the California Palace of the Legion of Honor, San Francisco, Calif., "The Korean Exhibition." Attendance, 100. |

1959

- January 15. Dr. Ettinghausen, at the annual Regents' dinner, Smithsonian Institution, "Objects Dealing with Christmas Themes in the Freer Gallery Collections." Attendance 34.
- January 16. Mr. Stern, to the Japan-American Society, Georgetown Presbyterian Church, Washington, D.C., "Hokusai." Attendance, 30.
- January 29. Dr. Cahill, to the College Art Association, Cleveland, Ohio, "Criteria of Evaluation in Chinese Criticism of Painting." Attendance, 60.
- January 30. Dr. Pope, at the Antiques Forum, Williamsburg, Va., "Chinese Export Porcelain in Perspective." Attendance, 395.
- February 3. Mr. Stern, at the Los Angeles County Museum, Los Angeles, Calif., "The Korean Exhibition." Attendance, 350.
- February 9. Mr. Stern, to the Society for Asian Arts, San Francisco, Calif., "Hokusai." Attendance, 150.
- March 17. Dr. Cahill, at the Fogg Art Museum, Cambridge, Mass., "Two Concepts of Painting in China." Attendance, 60.
- March 18. Dr. Cahill, at the Fogg Art Museum, Cambridge, Mass., "The Theory of Literati Painting." Attendance, 60.
- March 19. Dr. Cahill, at Harvard University, Cambridge, Mass., "Yüan Dynasty Painting." Attendance, 12.
- April 9. Dr. Pope, to the American Oriental Society, University of Michigan, Ann Arbor, Mich., "Notes on Saga of Porcelain: How Old Is Koimari?" Attendance, 100.
- April 10. Dr. Ettinghausen, to the American Oriental Society, University of Michigan, Ann Arbor, Mich., "Miniatures Related to the 'Demotte' *Shāh-nāme*." Attendance, 75.
- April 16. Mr. Stern, at Yale University, New Haven, Conn. "Hokusai the Painter." Attendance, 110.
- April 30. Mr. Stern, to the Japan Society, New York City, "Japanese Art, Visual Aspects." Attendance, 60.
- May 7. Dr. Pope, at the University of Virginia, Charlottesville, Va., "Temples of Angkor." Attendance, 175.
- May 23. Mr. Gettens, to the Eastern New York American Chemical Society, Top of the World Inn, Lake George, N.Y., "Adventures in Archaeological Chemistry." Attendance, 50.

Members of the staff traveled outside Washington on official business as follows:

1958

- June 20-
August 11. Dr. Pope, in Europe, examined objects in museums and private collections as follows: London: British Museum, Percival David Foundation, Victoria and Albert Museum, and six private collections; Amsterdam: Museum for Asiatic Art and one private collection; The Hague: One private collection; Brussels: Musée du Cinquantenaire and Stoclet Collection; Athens: Benaki Museum; Rome: Istituto Italiano per il Medio ed Estremo Oriente; Venice: Oriental Museum; Lugano: Dubosc Collection and Vanotti Collection.

1958

- July 1-3. Mr. Stern, in New York City with Dr. George Switzer of the U. S. National Museum, examined the Vetlesen jade collection, and arranged for transportation as a gift to the Smithsonian Institution.
- July 7. Mr. Gettens, with Dr. Harold Plenderleith of the British Museum, London, England, visited the Mellon Institute, Pittsburgh, Pa., where Dr. Robert Feller showed them installations.
- July 17-18. Mr. Gettens, with Dr. Harold Plenderleith, attended the Seminar on Museum Science at the Winterthur Museum, Winterthur, Del.
- September 3-11. Dr. Cahill, in Aspen, Colo., attended the "Conference on Chinese Thought."
- September 11. Mr. Wenley, in Ann Arbor, Mich., conferred with the Freer Fund Committee, head of the art department, and editors at the University of Michigan.
- September 12. Dr. Ettinghausen, in Baltimore, Md., examined Near Eastern manuscripts and miniatures in the Baltimore Museum of Art.
- September 12. Dr. Cahill, in Chicago, Ill., examined Chinese paintings at the Art Institute of Chicago.
- September 13-15. Dr. Cahill, in New York City, examined objects at dealers.
- September 15. Dr. Pope, in Baltimore, Md., examined one Japanese sculpture in the Baltimore Museum of Art.
- September 15-17. Mr. Stern, in Ann Arbor, Mich., consulted with Doctoral Committee at the University of Michigan.
- September 15-18. Mr. Gettens, in Boston, Mass., attended a Seminar on Application of Science in Examination of Works of Art at the Museum of Fine Arts; participated in the ceremonies to honor Edward Waldo Forbes, director emeritus of the Fogg Art Museum, on his 85th birthday.
- October 11-22. Dr. Ettinghausen, in Cleveland, Ohio, examined Rajasthani miniatures belonging to G. K. Kanoria, Calcutta, India, exhibited in the Cleveland Museum of Art; examined Mughal, Rajasthani, and Pahari miniatures in a private collection; examined and photographed 4 Mughal miniatures in the Cleveland Museum of Art; in Ann Arbor, Mich., examined 40 pieces of pottery in the Museum of Art, University of Michigan; examined 1 Persian manuscript and photographed 3 Persian miniatures in a private collection; in Detroit, Mich., examined 1 Indian miniature and 1 Egyptian ceremonial mace in the Detroit Institute of Art.
- October 22. Mr. Gettens and Miss Elisabeth H. West, in Upton, Long Island, N.Y., visited Brookhaven National Laboratory where technical matters were discussed with Dr. E. V. Sayre, and other members of the Chemistry Department.
- October 23-25. Dr. Pope, in New York City, examined 30 objects at dealers. Attended a meeting of the American Council of Learned Societies, Committee on Asia.
- October 23-25. Mr. Gettens, in Brooklyn, N.Y., attended a "Conference on Conservation" at the Brooklyn Museum. Served as a member of the ad hoc committee on Resolutions for Exploratory Conference on Conservation.

1958

- November 1. Mrs. Usilton and Mrs. Hogenson, in Baltimore, Md., attended an all-day meeting of Regional Catalogers of Maryland, Virginia, and District of Columbia at the Peabody Institute.
- November 3-4. Dr. Ettinghausen, in Baltimore, Md., examined 1 Christian-Arab dagger, 1 Turkish box, 1 Moroccan dagger, 4 Indian manuscripts, and 10 Indian miniatures in the Walters Art Gallery; did research work in their library.
- November 8-11. Mr. Stern, in New York City, examined 141 objects at dealers. Looked at the collections of the Museum of Modern Art; examined 30 pieces of Japanese porcelain and 1 Japanese painting at the Metropolitan Museum of Art.
- November 20-26. Dr. Cahill, in New York City, examined 30 Chinese paintings in private collections, and 88 objects at dealers.
- December 8-10. Dr. Cahill, in Boston and Cambridge, Mass., examined 86 Chinese paintings in the Museum of Fine Arts, and 24 Chinese paintings at the Fogg Art Museum.

1959

- February 1-24. Mr. Stern, in Los Angeles, Calif., examined 50 Far Eastern objects in the Los Angeles County Museum, and 62 objects in private collections; in San Diego, examined 60 Japanese objects in the Museum of Art; in Santa Barbara, examined 145 Chinese and Japanese objects in the Museum of Art, and 215 Far Eastern objects in private collections; in San Francisco, examined 40 Indian paintings at the De Young Memorial Museum, 406 objects belonging to various dealers, and 457 Far Eastern objects in private collections. In Kansas City, examined 207 Far Eastern objects in the William Rockhill Nelson Gallery of Art, and 35 Indian bronzes in a private collection. In Chicago, examined 43 Far Eastern objects in the Art Institute of Chicago, and 25 Japanese paintings in private collections.
- February 11. Dr. Ettinghausen, in Baltimore, Md., examined objects in the Walters Art Gallery.
- February 16-26. Mr. Gettens, in Upton, Long Island, N.Y., continued the spectrographic analysis of Chinese bronzes begun last year at the Brookhaven National Laboratory.
- February 16-27. Miss Elisabeth H. West, in Upton, Long Island, N.Y., continued the spectrographic analysis of Chinese bronzes begun last year at the Brookhaven National Laboratory.
- February 18-20. Dr. Ettinghausen, in New York City, examined objects at dealers.
- March 17-22. Dr. Cahill, in Cambridge, Mass., examined 12 Far Eastern paintings at the Fogg Art Museum, and 41 paintings in private collections; in Boston, examined 17 paintings at the Museum of Fine Arts.
- April 8-12. Dr. Pope, in Ann Arbor, Mich., attended a meeting of the American Oriental Society; examined 100 objects in the University Museum of Anthropology.
- April 8-14. Dr. Ettinghausen, in Ann Arbor, Mich., attended a meeting of the American Oriental Society; examined 155 Persian objects and 20 transparencies of Persian miniatures at a special exhibition in the Museum of the Near East.

1959

- April 15-17. Mr. Stern, in New Haven, Conn., examined 40 Japanese prints and 50 Japanese paintings at the Yale University Art Museum; in New York City, examined 160 objects belonging to dealers.
- April 24-29. Dr. Pope, in New York City, attended meetings of the American Council of Learned Societies, Joint Committee on the Award of Fellowships; examined 136 Far Eastern objects belonging to dealers.
- April 30-May 1. Mr. Stern, in New York City, examined 35 objects belonging to dealers.
- May 8. Dr. Pope, in Charlottesville, Va., examined 4 Chinese paintings and 15 pieces of Chinese pottery in a private collection.
- May 12-18. Dr. Pope, in New York City, attended meetings of the American Council of Learned Societies, Committee on Asia; examined a number of objects in the Metropolitan Museum of Art; in Boston, Mass., presided at meetings of the Far Eastern Ceramic Group at the Museum of Fine Arts.
- May 23-30. Mr. Stern, in Cambridge, Mass., conferred with Robert Treat Paine, Jr., at the Fogg Art Museum, and Prof. James N. Plumer of the University of Michigan; in New York City, examined 170 objects belonging to dealers, and 52 objects in two museums.
- May 23. Mr. Gettens, in Lake George, N.Y., attended meetings of the Eastern New York American Chemical Society.
- June 1-4. Mr. Gettens, in Pittsburgh, Pa., attended meetings of the American Association of Museums. He presided as chairman of the Temporary Committee of the International Institute for the Conservation of Museum Objects, at a meeting for the purpose of forming the American Group.

Mr. Gettens left for Europe on June 14, 1959, to attend meetings of the International Council of Museums in Copenhagen and Stockholm, and en route, to consult with colleagues and visit collections in Scotland, England, and Belgium.

As in former years, members of the staff undertook a wide variety of peripheral duties outside the Gallery, served on committees, held honorary posts, and received recognitions.

On June 9, 1959, the Gallery cooperated with the Dumbarton Oaks Research Library and Collection, Trustees for Harvard University, in sponsoring a performance of *Gagaku*, the musicians and dancers of the Imperial Japanese Household. This ancient company made its first journey outside of Japan, thanks to the interest and influence of Secretary General Dag Hammarskjöld, to perform before the United Nations in New York. A 2-week schedule followed under the auspices of the New York City Ballet Company; and it was the generosity of the latter organization that made possible the single appearance in Washington. Over 500 invited guests attended the production in the gardens of Dumbarton Oaks.

The Freer Gallery of Art again participated in the Wellesley-Vassar Washington Summer Intern Program designed for students interested in obtaining rounded experience in the general operation and purposes of a gallery, and in broadening familiarity with the field of art in general. Miss Nancy Orbison, Vassar College, Poughkeepsie, N.Y., served as our volunteer for this program during the summer of 1959.

Respectfully submitted.

A. G. WENLEY, *Director.*

Dr. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the National Air Museum

SIR: I have the honor to submit the following report on the activities of the National Air Museum for the fiscal year ended June 30, 1959:

On September 6, 1958, President Eisenhower signed the bill (S. 1958), originally introduced by Senator Clinton P. Anderson and passed by the 85th Congress, authorizing and directing the Regents of the Smithsonian Institution to prepare plans, including drawings and specifications, for the construction of a suitable building for a National Air Museum to be located on the site bounded by Fourth and Seventh Streets SW., Independence Avenue, and Jefferson Drive. Thus, with the passage of this act (Public Law 85-935), another step forward has been taken toward the provision of adequate housing for the National Air Museum. The architectural firm of Harbeson, Hough, Livingston & Larson, of Philadelphia, Pa., is making preliminary studies and an estimate of planning costs for the building.

A number of significant accessions were received. Among these were the first recovered nose cone from outer space, a replica of the Jupiter C rocket and satellite Explorer I, a recovered data capsule from outer space, some original documents of the early experiments in rocketry by Dr. Robert H. Goddard, and a Curtiss-Wright Jr. airplane.

Considerable progress was made in the improvement and preparation of storage and restoration facilities.

Plans for a new exhibit in the Aircraft Building were approved, and construction will begin this fall. It is expected that the new exhibit will be opened in the spring of 1960.

Information service in the form of technical, historical, and biographical information pertaining to the development of aviation, furnished to Government agencies, schools, research workers, authors, students, and the public, increased in scope and in volume during the year. Many useful acquisitions to the Museum's library, reference, and photographic files were received.

New staff members reporting for duty include Kenneth E. Newland, curator; Robert Meyer, junior curator; and Robert Wood, museum aide.

Walter M. Male, associate curator, has been assigned to Suitland, Md., as operations manager in charge of the Museum's restoration program.

ADVISORY BOARD

Although no meetings of the Advisory Board were held during the year, the members have been consulted from time to time on important museum activities. One member of the Board, Grover C. Loening, gave the Lester D. Gardner Lecture in Washington, under the sponsorship of the National Air Museum.

SPECIAL EVENTS

Several notable presentation ceremonies were held during the year. Outstanding was the presentation of the Jupiter C rocket and Explorer I satellite by Secretary of the Army Wilber M. Brucker, on January 31, 1959, the anniversary date of the placing of the first American satellite into orbit. Other special ceremonies included the presentation of a recovered data capsule by Gen. Bernard Schriever, U.S. Air Force; a working model of the Vanguard satellite, presented by Dr. John P. Hagen of NASA; and the first recovered nose cone, presented by Secretary of the Army Wilber M. Brucker. In each instance Dr. Carmichael accepted the gift for the Museum with appropriate remarks.

The Director attended the World Congress of Flight at Las Vegas, Nev., April 12-18, and from there proceeded to the National Aviation Educational Council held at Riverside, Calif., April 19-20, 1959.

The head curator and historian, Paul E. Garber, represented the Museum at a number of events identified with aviation history. These included the Vanguard satellite anniversary banquet; the annual meeting of the American Helicopter Society; the National Rocket Club annual banquet; the annual meeting of the Early Birds; and the National Postage Stamp Show. He delivered 13 lectures during the year and conducted 6 special tours of the Museum for groups of military visitors. He also participated in a number of television and radio programs during the year and paid visits to Hammondsport, New York, and St. Louis on Museum business.

Both the Director and head curator were appointed by the National Aeronautic Association as members of the committee to select the annual recipient of the National Frank G. Brewer Award for Aviation Education.

IMPROVEMENTS IN EXHIBITS

The aircraft, engines, and other aviation equipment scheduled for display in the new exhibit for the Aircraft Building are being cleaned, repaired, and made ready for exhibition.

A general cleaning and renovation of exhibits and some minor repairs were undertaken.

REPAIR, PRESERVATION, AND RESTORATION

A small office has been provided at the Suitland storage facility, and a paint and spray booth is under construction. A fabric department and document room are in process of planning. Additional machine tools and equipment have been acquired. Most of the aircraft and engines in the Aircraft Building have been moved to Suitland and are undergoing cleaning, repair, and preparation for storage or exhibition.

In anticipation of the restoration program which lies ahead in preparation for the new building, the Director has visited many aircraft factories and has received assurances of cooperation from the manufacturers by way of providing us with technical data, lending mechanics to assist in restoration and to advise on methods of display.

ASSISTANCE TO GOVERNMENT DEPARTMENTS

The National Air Museum has served many Government departments during the year. Among these were the Department of Justice in connection with patent litigation, the Voice of America, the Department of the Air Force, and the Department of the Navy.

PUBLIC INFORMATION SERVICES

Providing information to the public continues as a very active and growing function of the Museum. For example, telephone calls during the year requesting historical, technical, or biographical information on the development of aviation numbered more than 700 from Government agencies and more than 1,400 from other sources. Correspondence is averaging around 100 letters a week. Approximately 19,000 leaflets were distributed during the year, in addition to some 1,100 photographs and drawings.

The Museum continues to serve aircraft manufacturers, airlines, publishers, authors, schools and colleges, and many individual students, teachers, and research workers.

REFERENCE MATERIAL AND ACKNOWLEDGMENTS

Many useful and valuable additions to the reference files, photographic files, and library of the Museum were received during the year. These records and documents are helpful to the Museum staff in providing information service, authenticating data, and for research.

The cooperation of the following persons and organizations in providing this material is sincerely appreciated:

AIR FORCE, DEPARTMENT OF THE, AIR FORCE MUSEUM, Wright-Patterson Air Force Base, Ohio: Negatives of flight of Col. Charles A. Lindbergh and Anne Morrow Lindbergh in the Lockheed Sirius seaplane *Tingmissartog*, 1929. AIR UNIVERSITY, Maxwell Field, Ala.: Pamphlets of USAF Historical Studies No. 98.

- ARMY, DEPARTMENT OF THE, INFORMATION OFFICE, U.S. MILITARY ACADEMY, West Point, N.Y.: Photograph "Cenotaph at Post Cemetery," dedicated to Lt. Thomas Selfridge. PUBLIC INFORMATION OFFICE, MILITARY DISTRICT OF WASHINGTON, Gravelly Point, Va.: Pictorial record and articles relating to Wright-Selfridge flight. OFFICE OF THE CHIEF OF INFORMATION, Washington, D.C.: Tape recording of the presentation ceremony of the Explorer I. Photograph of Explorer I.
- ARTISTS AND WRITERS PRESS, INC., New York, N.Y. (Caroline Ungemah): The Story of Flight—A Giant Golden Book.
- BAUSCH & LOMB OPTICAL CO., Rochester, N.Y.: Copies of booklet "Reprint of First Exhibition of the Aeronautic Society of New York," at Morris Park, New York City, November 3, 1908.
- BEECH AIRCRAFT CORP., Wichita, Kans.: A collection of photographs and 3-view drawings of Beech aircraft.
- BOEING AIRPLANE CO., Washington, D.C.: Photographs of Boeing 707 jetplane.
- BRICK, MRS. KAY, Norwood, N.J.: Official programs of the Women's Transcontinental Races.
- BRONSON, C. L., Lookout Mountain, Tenn.: Photographs of Glenn H. Curtiss and Curtiss airplanes.
- BROWN, MAJ. KIMBROUGH S., USAF, Bedford, Mass.: A copy of his recent book "Von Richthofen and the Flying Circus."
- BURKE, JUSTIN J., Dubuque, Iowa: Notarized statement and supporting documents relating to and describing the first installation of navigation lights on military airplanes, Ellington Field, Tex., 1918.
- CAFFREY, FRANCIS J., Liverpool, N.Y.: A collection of pamphlets and material pertaining to aircraft and flight operations.
- CANADAIR LIMITED, Montreal, Canada: A collection of photographs and descriptive literature on Canadian aircraft.
- CASEY, LOUIS S., Washington, D.C.: A collection of handbooks pertaining to Consolidated PBY-5, Pratt and Whitney Twin Wasp C series, and Twin Wasp C3 series.
- CESSNA AIRCRAFT CO., Wichita, Kans.: A collection of photographs and a genealogy chart of Cessna aircraft. Photograph of Clyde V. Cessna and Dwayne L. Wallace, 1954. Three-view drawings of Cessna aircraft as follows: 305 A, B, and C; 321; 140A; 170A; 120; 140; H-001; DC-6; CW-6; C-106A; FC-1; C-165; T-37; LC-126; 170; 172; 175; 180; 182; 310 B and C; T-50; Monoplane; Gobel Special; and Glider.
- COHEN, COMDR. ALBERT M., USNR, Retired, Wynnewood, Pa.: A collection of photographs re: Brest, France, and vicinity, U.S. Navy Aviation Section, WWI.
- COOKE, DAVID C., Valley Stream, N.Y.: A copy of his book "Bomber Planes That Made History."
- CORNISH, J. J., 3d, Mississippi State University, State College, Miss.: A copy of his article "The Flight of Seeds."
- DEARBORN HISTORICAL MUSEUM, Dearborn, Mich.: Booklet entitled "Tin Goose."
- DEUTSCHES MUSEUM, Munchen, Germany: Fabric section duplicating the color scheme from the Fokker D-VII in possession of Deutsches Museum.
- EASTERN AIRLINES, New York, N.Y.: Photostats from Fokker Catalog re: Fokker Universal and Super Universal aircraft.
- EMMONS, CONANT, Washington, D.C.: Four glass negatives of Wright Type "A" airplane at Fort Myer, 1909.
- ESSO EXPORT CORP., New York, N.Y.: A collection of magazines (bound volumes): Flight, The Aeroplane, and Aviation Week.
- ESSO STANDARD OIL CO., W. H. KEPPEL, New York, N.Y.: A collection of reference material on Curtiss H-16 flying boat.

- FERRY SERVICE, INC., Pontiac, Mich.: Drawings of Stinson aircraft models with the exception of models 108 and L-5.
- FRANKLIN INSTITUTE, Philadelphia, Pa.: Blueprints of Wilford Gyroscaplane.
- FROYD, MRS. SHIRLEY B., Pasadena, Calif.: Newspaper and magazine clippings on aviation, period 1925-27.
- GOODWIN, GARLAND O., San Diego, Calif.: Drawing of Montgomery glider of 1883.
- GRIFFENHAGEN, GEORGE, Smithsonian Institution, Washington, D.C.: A collection of timetables for various airlines.
- GRUMMAN AIRCRAFT ENGINEERING CORP., Bethpage, N.Y.: A collection of specifications, brochures, and photographs of Grumman "Gulfstream" aircraft. Pilots' handbooks for Model F3F, and Erection and Maintenance manual for the F3F-1 aircraft.
- HALSEY, MISS MARION S., Washington, D.C.: Two aircraft identification booklets.
- HERRICK, MRS. GIRAUD P., New York, N.Y.: A collection of materials of the late Girard P. Herrick, *Records of Invention*; reference books; "Story of the Helicopter"; and engineers' handbooks.
- HILL, JAMES N. B., Boston, Mass.: Booklet entitled "Kites and Experiments in Aerial Photographs."
- HIXSON & JORGENSEN, INC., Los Angeles, Calif.: Lithographs, Leach "Heritage of the Air" series, copy proofs 1 through 5.
- HUTCHINSON, ROLAND V., Birmingham, Mich.: A collection of photographs of first DH-4 brought to the United States from England. Donated to NAM via A. V. Verville.
- JET PIONEERS ASSOCIATION, c/o GENERAL ELECTRIC Co., West Lynn, Mass.: Leather-bound looseleaf binder containing photographs of the Jet Pioneers of U.S.A.
- KALLIB, OTTO, New York, N.Y.: Roll of poster paper 30 feet in length on which is recorded by Kronfeld his important glider flights.
- LEE, FRED B., c/o OLIN MATHIESON CHEMICAL CORP., Washington, D.C.: Three books, *Aeronautical Annual* for 1895, 1896, and 1897. Three separate volumes.
- LOCKHEED AIRCRAFT CORP., Burbank, Calif.: A collection of photographs and 3-view drawings of Lockheed Sirius, reference and historical information on the aircraft.
- MASUNAGE, KANOSUKE, USHIO SHOBO PUBLISHING Co., Tokyo, Japan: A collection of photographs of Japanese and captured American aircraft: Army type 99 trainer, type 98 light bomber, Navy type 96 carrier fighter, Douglas DC-5, Boeing B-17E, Douglas A-20A, and Brewster F2A-2 "Buffalo."
- MCCOY, JOHN T., New York, N.Y.: Two paintings (reproductions), *The Wright Brothers at Fort Myer, Va., July 30, 1909*; and *Eugene Ely taking off from the U.S.S. Pennsylvania, January 18, 1911*.
- MCDONNELL AIRCRAFT CORP., St. Louis, Mo.: Two photocopies of 3-view drawing of McDonnell FH-1 Phantom.
- MIKESH, CAPT. ROBERT C., APO 994, San Francisco, Calif.: Color film of kite festival held in Japan.
- MILLER, REAR ADM. H. B., USN, Retired, New York, N.Y.: Collection of photographs of operational use of Curtiss F9C-2.
- MUNSON, H. A., Charlottesville, Va.: Booklet entitled "Santos-Dumont, Father of Aviation."
- NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS, LANGLEY FIELD LABORATORY, Va.: Reference material.
- NATIONAL BROADCASTING Co., New York, N.Y.: Transcript of Paul E. Garber's talk on his recollections of the Postal Aviation Service.
- NAVY, DEPARTMENT OF THE, BUREAU OF AERONAUTICS, Washington, D.C.: A collection of photographs of historic aircraft and aviation personages. Verville

- Aircraft Co.'s brochures on the Verville Air Coach and Verville Sports Training Plane. Drawings of HS2L and JN4D aircraft. Drawings of US-D4, Army Curtiss Racer, 1922, Navy Curtiss Seaplane Racer R2C-2, and PW-1.
- NELSON, CHARLES P., Lynn, Mass.: Typed copy of story of cruise of the ZR-1 *Shenandoah* from Lakehurst, N.J., to St. Louis, Mo., and return.
- PAN AMERICAN WORLD AIRWAYS SYSTEM, New York, N.Y.: Photostats of Lindbergh's survey report (Lockheed Sirius), background information on survey for Pan American. Photographs of Lindbergh's arrival at Belem.
- POTNAM'S, G. P., SONS, New York, N.Y.: Book entitled "Fighting Planes That Made History," by David Cooke.
- ROYAL CANADIAN AIR FORCE, S/L R. WOOD, Trenton, Ontario, Canada: Plans of aircraft (3 sets of 8 plans) of RCAF types Fairchild 71, A. W. Atlas, DeHavilland-60, Vickers Bedette, Curtiss Canuck, Curtiss HS2L, Avro 504K, and A. W. Siskin.
- SCHWEIZER AIRCRAFT CORP., Elmira, N.Y.: A collection of photographs and 3-view drawings of Schweizer 2-22C, 1-23G, and 1-30 experimental light plane.
- SIKORSKY AIRCRAFT Co., Stratford, Conn.: A collection of photographs and specifications on Sikorsky S-38, S-39, S-40, S-51, S-52, S-55, S-56, S-58, S-62, and H-18. Drawings and photographs of PS-3 (S-38). Photographs of Sikorsky HSS-2 Amphibious Helicopter.
- SUBMARINE LIBRARY, Groton, Conn.: A collection of drawings and photographs of Loening amphibians.
- THOMPSON, MRS. R., Huntington, Long Island, N.Y.: Photographs and magazine article, "Cross Country Flight of 'Yankee Doodle,'" by Harry J. Tucker, and "Wings for Our Business." Two 8- by 10-inch photographs of Lockheed Vega *Yankee Doodle*.
- THOMPSON PRODUCTS, INC., Cleveland, Ohio: Lithographs of Hubbell paintings. Various sets representing events or periods in aviation history.
- VICTORIA and ALBERT MUSEUM, South Kensington, London, England: January 1959 issue of *Journal of the Royal Society of Arts*.
- WEAVER, CAPT. T. C., Fairborn, Ohio: A collection of photographs of racing aircraft.

ACCESSIONS

Additions to the National aeronautical collections received and recorded during the fiscal year 1959 totaled 341 specimens in 56 separate accessions from 38 sources.

Those from Government departments are entered as transfers; others were received as gifts except as noted.

AIR FORCE, DEPARTMENT OF THE, Washington, D.C.: The "Pioneer-I" exhibit consisting of a scale model of a Douglas Thor ballistic missile and related electrical and mechanical display units, illustrating the first attempts made in August and October 1958 to place a man-made object in an orbit around the moon. Although not successful, useful information was obtained about the radiation belt surrounding the earth. (NAM 1023.) The "Data-Sphere," an instrumented capsule containing a tape recorder and other apparatus for receiving and preserving data during the launching, climb, and descent of a Thor ballistic missile. This one is the first of the series to be recovered. (NAM 1043.) AIR FORCE MUSEUM, Wright-Patterson Air Force Base, Ohio: A German Nagler-Rolz helicopter, type NR-54 V2. An early example of a one-man helicopter, it was developed during World War II. On each of its two rotor blades an 8-hp. Argus engine with a 23-inch wooden propeller is mounted, about midway, to revolve the rotor. (NAM 1019.) A group of 11

scale models, 1:48 size, of Beechcraft, Boeing, Curtiss, North American, and Stearman airplanes used by the U.S. Air Force or its predecessor units. (NAM 1029.) The DM-1 delta-winged glider designed by Alexander Lippisch in Germany during World War II as a primary step in the development of a supersonic airplane. This is one of the first configurations of the delta wing. (NAM 1041.)

ARMY, DEPARTMENT OF THE, Washington, D.C.: Nose cone of the Jupiter "C" missile. The first object recovered after returning from outer space. This cone was featured in a television broadcast by President Eisenhower on November 7, 1957. (NAM 1020.) The Jupiter "C" missile, a duplicate of the vehicle produced by the Chrysler Corp. which on January 31, 1958, launched the Explorer I. This was America's first satellite to be propelled into orbit. This vehicle was presented to the Museum on the first anniversary of that historic occasion. (NAM 1031.)

BEECH AIRCRAFT CORP., Wichita Kans.: Scale models, 1:16 size, of two airplanes developed by Walter Beech and his associates, the Travelair biplane of 1926 (NAM 1013) and the Travelair Mystery S of 1929 (NAM 1003).

BLACK, MRS. PALMA, Bakersville, Calif.: A piece of the gas cell fabric of the U.S. naval airship *Shenandoah*, 1925. (NAM 1009.)

BRITISH OVERSEAS AIRWAYS CORP., London, England: A scale model, 1:72 size, of the original Comet-I jet airliner which inaugurated jet-engined civil transport service in 1952. (NAM 1035.)

CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, Calif.: A WAC Corporal missile and base. This is a short-range ballistic missile, built by the Firestone Tire & Rubber Co. and in current use by the U.S. Army. (NAM 1006.)

CESSNA AIRCRAFT CO., Wichita, Kans.: A scale model, 1:40 size, of the Cessna T-37 2-place, twin-jet airplane now in service with the U.S. Air Force for primary training. (NAM 1002.)

CHANCE VUGHT AIRCRAFT, INC., Dallas, Tex.: A scale model, 1:16 size, of the U.S. Navy carrier-based F8U-1 "Crusader." This type of airplane, with a speed of more than 1,000 m.p.h., was the subject for the Robert J. Collier Trophy award in 1957 and earned for the Chance Vought corporation the Navy Bureau of Aeronautics' first Certificate of Merit. (NAM 1037.)

CIGAL, ALDO L., Southwick, Mass.: A 1:16 size model of the Pratt & Whitney J57 jet engine (loan). (NAM 1025.)

CONVAIR, Division of GENERAL DYNAMICS CORP., San Diego, Calif.: A scale model, 1:48 size, of the Consolidated-Vultee "Convair-liner" 240, the first post-World War II commercial transport developed by this corporation, 1947. It is a twin-engined, medium-range, 40-passenger transport. Also a 1:16 size model of the Convair XFY-1 "Pogo Stick," an experimental vertically rising delta-wing fighter developed for the U.S. Navy. It made its first free vertical takeoff and landing on August 2, 1954, and 3 months later made the conversion from vertical to horizontal flight and back to vertical for a tail-first landing. The original XFY-1 is being reserved for the National Air Museum by the Department of the Navy. (NAM 1004.)

DAVIES, THE HONORABLE JOSEPH (deceased), Washington, D.C.: An autographed photograph of Brig. Gen. William Mitchell as a captain in the U.S. Army, 1915. (NAM 999.)

DOLAN, COL. CARL H., Greenwich, Conn.: A collection of objects associated with the aeronautical interests and career of this member of the Early Birds and the Lafayette Escadrille. Included are military maps, instruments, and mementos of the renowned American ace Maj. Raoul Lufbery. (NAM 1027.)

DOOLITTLE, GEN. JAMES H., San Francisco, Calif.: A uniform worn during World War II by the donor. (NAM 1044.)

- GILPATRIC, MRS. M. S., New York, N.Y.: A trophy cup presented to her son, Guy Gilpatric, in 1912 for establishing an American 2-man altitude record of 4,665 feet. This was made in a Deperdussin monoplane at Dominguez Field, Los Angeles, when he was 16 years old. (NAM 1034.)
- GODDARD, MRS. ROBERT H., Worcester, Mass.: A set of 20 volumes of typed transcriptions and photographs recording the pioneer research in rocketry by Dr. Robert H. Goddard for the period 1921-41. (NAM 1000.) A selection of personal memorabilia of Dr. Goddard, including his purse, two penknives, his watch, fraternity pin, and the original manuscript of his work "Methods of Reaching High Altitudes." (NAM 1008.) A group of seven notebooks in which Dr. Goddard entered results of his experiments. (NAM 1021.) The academic hood received by Dr. Goddard with his degree of doctor of science from Clark University, June 2, 1945. (NAM 1024.) Equipment used by Dr. Goddard in his research, including laboratory apparatus and parts of his liquid-fueled rockets. (NAM 1033.) An oil painting of Dr. Goddard pictured at the moment when his 1926 rocket was fired. The artist, Robert Fawcett, was commissioned for this painting by the John Hancock Mutual Life Insurance Co. (NAM 1052.)
- GREGORY, MRS. LOUIS FRANKLIN, Shelby, Miss.: Photograph of the Sikorsky XR-4 helicopter with Orville Wright, Igor Sikorsky, and Gen. F. Gregory, autographed by these men. (NAM 1045.)
- HANSON, RICHARD, Washington, D.C.: A German World War I airspeed indicator. (NAM 1028.)
- HUBBELL, CHARLES, Cleveland, Ohio: A scale model, 1:16 size, of the Wright Co. "Baby Grand" Gordon Bennett Race airplane of 1910 (purchase). (NAM 1050.)
- KELLY, HOWARD A., JR., Baltimore, Md.: Gloves worn by Hubert Latham while flying over Baltimore in an Antoinette airplane, November 7, 1910, and a note written by this famous French pilot. (NAM 1014.)
- KELSEY, WALTER, Tarrytown, N.Y.: A clock and three instrument panel instruction plates from a SPAD XIII airplane of World War I. (NAM 1005.)
- LAHM, GEN. FRANK P., USAF, Retired, Huron, Ohio: A medal honoring General Lahm, sculptured by C. L. Schmitz for the Medal of the Month founded by Miss Felicity Buranelli. (NAM 1001.)
- MARTIN, MISS DELLA, Los Angeles, Calif.: The personal memorabilia of Glenn L. Martin, consisting of scale models and paintings of Martin aircraft, trophies, medals and awards, certificates of membership, photographs, and drawings. (NAM 1046.)
- MAYTAG, ROBERT E., Newton, Iowa: A Curtiss-Wright Junior airplane, a 2-place high-wing monoplane, with a pusher engine, popular as a personal aircraft during the 1930's. (NAM 1042.)
- NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS, Langley Field, Va.: A supersonic high-speed propeller designed for use on the McDonnell F-88 aircraft. (NAM 1010.) (See also NAM 1054.)
- NAVY, DEPARTMENT OF THE, Washington, D.C.: A catapult model, type XC-57, showing the mechanism, above and below deck, for operating the steam-powered catapults currently used for launching airplanes from carriers. (NAM 1007.) Scale models of a ZPN airship, HUP-2 helicopter, and HSL-1 helicopter. (NAM 1011.) A selection of aerodynamic models of aircraft and missiles showing recent developments tested at the David Taylor Model Basin. (NAM 1030.) A Sparrow-II guided missile. (NAM 1041.) A radio removed from the wreck of the U.S. naval airship *Shenandoah*, 1925. (NAM 1047.) An interplane strut from the NC-4 flying boat which made the first flight across the Atlantic Ocean, Rockaway, Long Island, to Plymouth, Eng-

- land, with intermediate stops, via the Azores, May 8-31, 1919. (NAM 1048.) A wing rib of the type used in this aircraft. (NAM 1049.) NAVAL RESEARCH LABORATORY (with the NATIONAL AERONAUTICS AND SPACE AGENCY), Washington, D.C.: An operable replica of the Vanguard-I satellite embodying a light-activated sound-producing mechanism. This was presented on March 17, 1959, the first anniversary of the launching of this satellite, which, it is predicted, will remain in orbit for 200 years or more. (NAM 1054.)
- NEVIN, ROBERT S., Denver, Colo.: A scale model, 1:16 size, of the Wright Co. HS airplane, 1915 (purchase). (NAM 1053.)
- NEWCOMB, CHARLES, Trappe, Md.: A scale model, 1:16 size, of the Wright Co. "D" airplanes, 1912 (purchase.) (NAM 1017.)
- NORTH AMERICAN AVIATION, INC., Columbus, Ohio: A scale model, 1:16 size, of the U.S. Navy A3J Vigilante, in current use as a carrier-based fighter-reconnaissance airplane. (NAM 1038.)
- SEFTON, THOMAS W., San Diego, Calif.: An aircraft radio antenna fairlead of the type used with radio equipment in U.S. Navy aircraft during World War II. (NAM 1018.)
- SHIPTON, DAVID H., Delavan, Ill.: A scale model, 1:48 size, of the Curtiss-Wright "Condor" 18-passenger, twin-engined biplane transport of 1934. (NAM 1026.)
- SIMMONS, MRS. O. G., and daughters, Arlington, Va.: A trophy cup commemorating the first airmail flight in the State of New Jersey, made by O. G. Simmons in a Wright type B twin-float seaplane flying between Amboy and South Amboy, July 4, 1912. (NAM 1039.)
- SMITHSONIAN INSTITUTION, NATIONAL AIR MUSEUM, Washington, D.C.: A plaster copy of the original sculpture of the Aero Club of America gold medal. Cast made in the Museum shop by Joseph A. Atchinson from original lent by Robert L. Perry whose grandfather, A. Holland Forbes, was president in 1910 of that club, founded in 1905 (purchase). (NAM 1032.) U.S. NATIONAL MUSEUM, DIVISION OF MILITARY HISTORY, Washington, D.C.: Two aviator helmets with inserted radio earphones, used in World War I. (NAM 1051.)
- TRACY, DANIEL, Lakewood, Ohio: A scale model, 1:16 size, of the Verville-Sperry Racer, winner of the Pulitzer Trophy, 1924 (purchase). (NAM 1016.)
- UNITED AIRCRAFT CORP., SIKORSKY DIVISION, Stratford, Conn.: Scale models, 1:50 size, of the S-58 and H-37 helicopters. (NAM 1015.)
- WHEELER, LESLIE, Binghamton, N.Y.: A model airplane engine of the Rogers type, 1932-33. (NAM 1036.)
- WILSON, THE HONORABLE ROBERT, San Diego, Calif.: The original holograph manuscript of "Soaring Flight," by John J. Montgomery, noted pioneer of gliding in America; written about 1895 (loan). (NAM 1012.)
- WINZEN RESEARCH, INC., Minneapolis, Minn.: A certificate awarded by the Federation Aeronautique Internationale to Maj. David G. Simons for establishing a world altitude record of 30,942 meters (nearly 102,000 feet) with a balloon made by the donors. The ascent was made over Minnesota in connection with the U.S. Air Force Aero-Medical Field Laboratory's high-altitude research program, identified by code name "Manhigh-II." The aeronaut was aloft for 32 hours. (NAM 1022.)

Respectfully submitted.

PHILIP S. HOPKINS, *Director.*

Dr. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the National Zoological Park

SIR: I have the honor to submit the following report on the activities of the National Zoological Park for the fiscal year ended June 30, 1959:

EXHIBITS

Following the plan announced last year, the National Zoological Park made good progress this year toward its goal of emphasizing the exhibition of North American animals and acquired several species native to this continent that had not been seen in the collection for many years.

The most publicized event of the year was the transportation of a herd of 14 reindeer and 1 caribou from Kotzebue, north of the Arctic Circle, to Washington, D.C. The animals, comprising a gift from the new State of Alaska to President Eisenhower, arrived here in time to take part in the annual "Pageant of Peace" held at Christmas on the Mall. J. Lear Grimmer, Associate Director of the National Zoological Park, and Charles Thomas, senior keeper of the large-mammal division, flew to Alaska and took part in the actual capture of the reindeer, which came from a herd that is under the management of the Bureau of Indian Affairs, Department of the Interior. Without a single loss the animals were flown to Anchorage, taken by the Alaska Railroad to Seward, shipped by the Alaska Steamship Co.'s SS *Iliamna* (captained by "Blackie" Selig) to Seattle, and then brought across country by Consolidated Freightways. They arrived in Washington on December 11 and were formally presented by Roger Ernst, Assistant Secretary of the Department of the Interior, to Homer Gruenther, Presidential Assistant, representing the Chief Executive and the people of the United States. The herd has been established in the Zoo with the addition of four fawns.

Mr. Grimmer also undertook an expedition to British Guiana, under the auspices of the Smithsonian Institution and the National Geographic Society. His purpose was to observe hoatzins in their native habitat. These strange birds, which somewhat resemble pheasants, occur along the northern coast of South America and have never been exhibited in any American zoo. His studies have convinced him that under proper conditions these birds can be kept in captivity. A

list of live animals collected by Mr. Grimmer in British Guiana follows:

22 Cook's tree boas	7 tawny-bellied seed-eaters
Vine snake	2 Swainson's grackles
2 yellow tegus	2 rice grosbeaks
Ameiva lizard	3 shiny cowbirds
Anaconda	3 lesser yellow finches
British Guiana green lizard	5 red-breasted marshbirds
Whipsnake	7 ground doves
4 common jacanas	12 hoatzins
2 black-throated cardinals	2 agoutis

In addition, a small collection of museum specimens of animals indigenous to the Abary River region was added to the accessions of the U.S. National Museum.

GIFTS

The Rocky Mountain goat had not been represented in the Zoo for many years, and therefore the gift from the Montana State Fish and Game Commission of a trio of these spectacular animals was much appreciated. From the same source came also a herd of five prong-horn antelopes.

Ross E. Wilson, vice president and general manager of the Firestone Rubber Co., presented a fine West African leopard from Harbel, Liberia.

Dr. Hubert Fringes, of Pennsylvania State University, who has been doing research on the care of albatrosses in captivity, presented a group of two Laysan albatrosses and three of the black-footed variety. Thanks to the discovery of the need for salt in the diet of sea birds, these birds, which usually do not do well in captivity, are thriving. Another Laysan albatross was added to the group as a gift from Dr. W. J. Carr, of Bucknell University.

The Fish and Wildlife Service of the Department of the Interior continued to cooperate in the procurement of desirable species of North American animals and birds. During the past year this agency has secured for the Zoo a caribou from Alaska, a northern porcupine, a white-fronted goose, 2 horned grebes, 10 greater scaups, 2 redheads, and 2 wood ducks. In June the Service offered the Zoo a polar bear cub that had been captured in Alaska. Owing to the fact that the Zoo had had to absorb a Wage Board increase in salaries, funds were embarrassingly low in the last quarter of the fiscal year, and there was no money to pay the cub's air transportation to Washington. Station WMAL-TV volunteered to have the little bear flown to the Zoo, where it has already become a great favorite with the visiting public.

LEGEND FOR MAP OF NATIONAL ZOOLOGICAL PARK

- | | |
|-------------------------------|---------------------------------|
| 1. Hooved stock. | 19. Camels. |
| 2. Equines. | 20. Small mammals. |
| 3. Llamas. | 21. Virginia deer. |
| 4. Deer. | 22. Elk. |
| 5. Deer. | 23. Deer. |
| 6. Deer. | 24. Wolves. |
| 7. Flight cage. | 25. Foxes. |
| 8. Elephants. | 26. Sea-lions. |
| 9. Eagle cage. | 27. Beavers. |
| 10. Black swans. | 28. Raccoons. |
| 11. Flight cage. | 29. Prairie dogs. |
| 12. Condor cage. | 30. Bears. |
| 13. Birds. | 31. Antelopes. |
| 14. Crane yards. | 32. Reptiles. |
| 15. Great flightless birds. | 33. Small cats. |
| 16. Pheasants. | 34. Monkeys. |
| 17. Flight cage. | 35. Lions. |
| 18. Mountain goats and sheep. | 36. Waterfowl. |
| A. Hay barn. | G. Heating plant. |
| B. Service roads. | H. Shop. |
| C. Parking areas. | I. Restrooms, police, first aid |
| D. Incinerators. | J. Restaurant. |
| E. Clock. | K. Bridle paths. |
| F. Garage. | |



MAP OF NATIONAL ZOOLOGICAL PARK
(For explanation, see opposite page.)

The Maryland State Game Commission gave the Zoo a pair of wild turkeys, which have hatched four eggs.

The Maine State Game Department at Milo trapped a fisher for the National Zoo. This is the rarest and most valuable of American fur-bearing animals and had not been exhibited here for more than 30 years.

The Zoo is fortunate in having among its friends members of the Armed Forces who, when stationed abroad, are always searching for rare and interesting animals. Dr. Robert E. Kuntz, of the Navy Medical Research Unit in Taipei, Taiwan, sent a number of specimens, including a family of three pangolins—father, mother, and baby. Lt. Col. Robert Traub, stationed at Kuala Lumpur, Malaya, sent two species of squirrels as well as a number of particularly interesting reptiles. Other animals collected by these men are included in the following list of gifts of special interest:

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|---|---|
| Allen, George J., Salt Lake City, Utah, 2 junglefowl. | Kilham, Dr. Lawrence, Bethesda, Md., African crocodile (hatched from egg taken near Murchison Falls, Uganda). |
| Aquarium, Department of Commerce, Washington, D.C., American egret. | Kuntz, Dr. Robert E. Taipei, Taiwan, 4 pangolins, 5 Formosan civets of 2 species, 2 Formosan badgers, 2 Formosan flying squirrels, Malayan fishing owl, 7 Formosan red-billed pies, 6 many-banded kraits, 13 Taiwan cobras, 3 habus, 2 palm vipers, 2 Pope's pit vipers, 11 greater Indian rat snakes, 3 Formosan rat snakes, 10 water snakes, 11 pit vipers. |
| Beatty, Charles, Washington, D.C., spiny-tailed iguana. | Lichtenecker, Dr. Karl E., Austrian Embassy, Washington, D.C., collection of 18 species of European snakes and lizards. |
| Carter, Dr. Hill, Washington, D.C., red-shouldered hawk. | Long Fence Co., Washington, D.C., peahen. |
| Clark, W. B., Alexandria, Va., 2 sparrow hawks. | Long, Gerald, Falls Church, Va., Virginia deer. |
| DePrato, Mario, Langley Park, Md., 4 five-lined skinks, 4 American toads, 2 mud turtles, snapping turtle. | McHale, J. P., Chicago, Ill., 7 Reeves's turtles. |
| Farrel, Mrs. D. M., Cabin John, Md., Philippine macaque, Javan macaque and hybrid offspring. | Metzler, John, Arlington, Va., red-tailed hawk. |
| Grayson, William C., Upperville, Va., 12 wood ducks. | Moorhead, Thornton, Washington, D.C., Formosan macaque. |
| Greeson, L. E., Arlington, Va., 2 white-tailed antelope squirrels. | Newill, Dr. D. S., Connellsville, Pa., 5 red junglefowl. |
| Grimes, Mrs. E. D., Washington, D.C., yellow and blue macaw. | Nottingham, Mrs. F., Indian Head, Md., golden pheasant. |
| Haack, Miss Mildred A., Washington, D.C., African lovebird. | Posey, Calvert, R., Nanjemoy, Md., great horned owl. |
| Hillman, Eric, Washington, D.C., diamondback terrapin. | |
| Housholder, Bob, Phoenix, Ariz., Texas red wolf. | |
| Hubbard, Scott, Washington, D.C., kinkajou. | |
| Jones, Mrs. Beatrice, Chevy Chase, Md., sulphur-crested toucan. | |
| Keeler, W., Falls Church, Va., 7 species of local snakes. | |

Sawyers, Mrs. Thomas R., Arlington, Va., double yellow-headed Amazon parrot.

Siere, José Gomez, Washington, D.C., 2 agoutis.

Styve, Mrs. Lauritz, Arlington, Va., short-eared owl.

Thomas, Charles, Washington, D.C., 3 Reeves's turtles.

Traub, Lt. Col. Robert, Kuala Lumpur, Malaya, small-clawed otter, 2 striped ground squirrels, 2 *Dremomys* squirrels, racket-tailed drongo, rufous-collared kingfisher,

orange-throated barbet, pygmy owl, 2 monitor lizards, flying lizard, skink lizard, mangrove snake, fat-cheeked water snake, elephant trunk snake, Wagler viper, flying snake, 4 geckos of 2 species, 9 lizards of 5 different species.

Woodward & Lothrop, Washington, D.C., 7 Humboldt's penguins, 2 fallow deer.

Young, Robert, Wheaton, Md., 3 diamondback terrapins.

Xanten, William, Jr., Washington, D.C., collection of Florida reptiles.

PURCHASES

The first Dall sheep ever to be exhibited in an American zoo were added to the collection this past year. The young animals are females, and prospects are bright for the addition of a ram within the next few months.

A great rarity purchased this year was a pair of Pallas's cats which had never before been exhibited in the collection. Other purchases of interest were:

2 serval cats
2 pig-tailed macaques
3 pygmy marmosets
Celebes crested ape
3 cottontop marmosets
Canada lynx
2 capybaras
2 mute swans
1 gray hornbill

Spectacled owl
Jackson's hornbill
Bellbird
Scarlet cock-of-the-rock
2 black-and-white turacos
Andean condor
2 Bateleur eagles
4 species of sunbirds
1 green jay

EXCHANGES

By the judicious use of exchanges made with other zoos and with individuals, the following animals were obtained:

Audubon Park Zoo, New Orleans, La., 2 aningas, 2 least bitterns.

Buffalo Zoo, Buffalo, N.Y., 2 milk snakes, 2 African soft-shelled turtles.

Calcutta Zoo, Calcutta, India, 5 Indian squirrels, 3 lesser pandas.

Calgary Zoo, Calgary, Alberta, wolferine, Canada lynx, 2 golden eagles, 2 pine martens.

Campbell, E., Detroit, Mich., 4 Bahama boas.

Chicago Zoological Park, Brookfield, Ill., ibex, 3 dingoes, 2 sitatungas.

Cleveland Zoo, Cleveland, Ohio, 2 mousebirds.

Freiheit, Clayton, Buffalo, N.Y., axolotl, 3 rhinoceros vipers, 2 prehensile-tailed vipers, 2 African soft-shelled tortoises.

Houston Zoo, Houston, Tex., a collection of 9 species of southwestern reptiles.

New York Zoological Park, New York, N.Y., 5 rhinoceros vipers, 10 puff adders (born in New York Zoo).

Riverside Park Zoo, Scottsbluff, Nebr., American badger.

San Antonio Zoo, San Antonio, Tex., Cape hunting dog, 6 boat-tailed grackles, 2 Hildebrandt's francolins, 7 Erckel's francolins, 2 fulvous tree ducks, 7 banded plovers.

DEPOSITS

The Zoo accepts for deposit only those animals that will make attractive additions to the collection, and even in such instances lack of proper housing often makes it necessary to refuse animals offered for temporary exhibition.

The offer of the National Aquarium Society of Washington to set up and maintain an exhibition of tropical fishes in the aquarium section of the reptile house was a welcome one. Members of the society have contributed tanks, filters, aerators, and a collection of fishes. The fishes belong to individual members of the Aquarium Society and will be returned to them when a new exhibition of different species is installed. This rotating or changing display should be a very attractive one for visitors.

For many years the National Zoological Park has exhibited a female Przewalski's wild horse, a species extinct in the wild and represented only by a few individuals in zoos in various parts of the world. Although the animal was assumed to be beyond breeding age, she had had foals in the past. She was mated with a stallion obtained on deposit from the Catskill Game Farm in New York, but without results, and on June 6 the mare died at the ripe old age of 33.

BIRTHS AND HATCHINGS

One of the signs that an animal is doing well in captivity is its ability to reproduce its kind, and, as the following list shows, the number of mammals, birds, and reptiles born in the National Zoological Park during the year is gratifying.

The outstanding birth of the year was that of a female wisent, which has been duly registered with the Wisent Society of Europe. These animals are now so scarce that careful records are kept of all that are born or die. Unfortunately the mother died 6 weeks after the baby was born; the young one, however, is thriving.

Other "firsts" for this Zoo included Cape hunting dogs, a striped hyena, a galago, a squirrel monkey, and an owl monkey, all of which are noteworthy by any zoo's standards.

Because of their curious life history, the hatching of Surinam toads in captivity is always of interest. For the second year one of the Zoo's females laid eggs; the male carefully embedded them in her back, and 35 little toads eventually emerged.

Zoo officials were gratified when the young pair of hippopotamuses purchased in 1956 and 1957 produced their first young one. These were bought as replacements for the old pair, Bongo and Pinky, which had been here since 1914 and 1939, respectively. The old pair are still here; Bongo sired seven young ones by his first mate, Mom, who came to the Zoo in 1911 and died in 1930. Several young ones were born to Pinky, but she raised none of them. The new female, Arusha,

seems to be a good mother, and it is hoped the baby will be the first of a long line such as the Zoo had many years ago.

MAMMALS

Scientific name	Common name	Number
<i>Aotus trivirgatus</i>	Douroucouli monkey.....	1
<i>Axis axis</i>	Axis deer.....	2
<i>Bison bonasus</i>	Wisent or European bison.....	1
<i>Canis antarcticus</i>	Dingo.....	7
<i>Cebus albifrons</i>	Capuchin monkey.....	1
<i>Cebus sp.</i>	Capuchin monkey.....	1
<i>Cercocebus fuliginosus</i>	Sooty mangabey.....	1
<i>Cercopithecus neglectus</i>	DeBrazza's monkey.....	1
<i>Cervus canadensis</i>	American elk.....	1
<i>Cervus elaphus</i>	Red deer.....	2
<i>Cervus nippon</i>	Sika deer.....	1
<i>Choloepus didactylus</i>	Two-toed sloth.....	1
<i>Cynomys ludovicianus</i>	Prairie dog.....	7
<i>Dama dama</i>	{ Brown fallow deer.....	5
	{ White fallow deer.....	2
<i>Equus burchelli boehmi</i>	Grant's zebra.....	1
<i>Galago senegalensis</i>	Galago.....	1
<i>Genetta genetta neumanni</i>	Genet.....	4
<i>Hippopotamus amphibius</i>	Hippopotamus.....	1
<i>Hyaena hyaena</i>	Striped hyena.....	1
<i>Hylobates agilis</i> × <i>H. lar pileatus</i>	Hybrid gibbon.....	1
<i>Hylobates lar</i> × <i>H. agilis</i> × <i>H. lar pileatus</i>	Hybrid gibbon.....	1
<i>Hypsiprymnodon moschatus</i>	Rat kangaroo.....	7
<i>Hystrix galeata</i>	African porcupine.....	2
<i>Jaculus aegyptius</i>	Egyptian gerbil.....	3
<i>Lama glama</i>	Llama.....	4
<i>Lama pacos</i>	Alpaca.....	1
<i>Lycaon pictus</i>	Cape hunting dog.....	5
<i>Macaca mulatta</i>	Rhesus monkey.....	1
<i>Macaca philippensis</i> × <i>M. irus</i>	Hybrid macaque.....	1
<i>Macaca sylvanus</i>	Barbary ape.....	3
<i>Meriones unguiculatus</i>	Mongolian gerbil.....	6
<i>Nasua narica</i>	Coatimundi.....	3
<i>Odocoileus virginianus</i>	Virginia deer.....	5
<i>Pachyuromys duprasi</i>	Fat-tailed gerbil.....	16
<i>Pan satyrus</i>	Chimpanzee.....	1
<i>Panthera leo</i>	Lion.....	4
<i>Rangifer tarandus</i>	Reindeer.....	7
<i>Saimiri sciureus</i>	Squirrel monkey.....	1
<i>Thalarcos maritimus</i> × <i>Ursus middendorffi</i>	Hybrid bear (2d generation).....	3
<i>Ursus horribilis</i>	Grizzly bear.....	3
<i>Vulpes fulva</i>	Red fox.....	4

BIRDS

<i>Aix sponsa</i>	Wood duck.....	22
<i>Anas platyrhynchos</i>	Mallard duck.....	4
<i>Chrysolophus pictus</i>	Golden pheasant.....	1
<i>Columba livia</i>	Homing pigeon.....	1
<i>Cygnus cygnus</i>	Whooper swan.....	2

Scientific name	Common name	Number
<i>Dendrocygna autumnalis</i>	Black-bellied tree duck.....	3
<i>Dendrocygna galeata</i>	Mandarin duck.....	3
<i>Gallus gallus</i>	Red junglefowl.....	5
<i>Gallus leucomelanus</i>	Nepal pheasant.....	3
<i>Larus dominicanus</i>	Kelp gull.....	2
<i>Meleagris gallopavo</i>	Wild turkey.....	10
<i>Melospiza undulatus</i>	Grass parakeet.....	6
<i>Nycticorax nycticorax hoactli</i>	Black-crowned night heron.....	8
<i>Pavo cristatus</i>	Peafowl.....	9

REPTILES

<i>Ancistrodon mokeson</i>	Copperhead.....	11
<i>Chelydra serpentina</i>	Snapping turtle.....	18
<i>Chrysemys picta</i>	Painted turtle.....	4
<i>Clemmys insculpta</i>	Wood turtle.....	2
<i>Crotalus atrox</i>	Western diamond-backed rattle- snake.....	10
<i>Egernia whitei</i>	White's skink.....	2
<i>Natrix insularum</i>	Island water snake.....	41
<i>Natrix rhombifera</i>	Diamondback water snake.....	35
<i>Pipa pipa</i>	Surinam toad.....	35
<i>Pseudemys</i> sp.....	Red-lined turtle.....	25
<i>Sistrurus catenatus</i>	Massasauga.....	10
<i>Sistrurus milliaris</i>	Pygmy rattlesnake.....	8
<i>Terrapene carolina</i>	Box turtle.....	3
<i>Thamnophis sirtalis</i>	Garter snake.....	1

ARTHROPODS

<i>Pandinus imperator</i>	Giant black African scorpion.....	10
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The importance of a zoological collection rests, to a large extent, upon the diversity and scope of its taxonomic representation throughout the whole of the Animal Kingdom. The National Zoological Park has enjoyed some measure of success in efforts to add representative species belonging to little-known or absent families.

The total number of accessions for the year was 1,286. This includes gifts, purchases, exchanges, deposits, births, and hatchlings. Several minor species which are best displayed in large numbers do not have an individual count, merely being listed as "many."

STATUS OF THE COLLECTION

Class	Orders	Families	Species or subspecies	Individuals
Mammals.....	13	49	234	628
Birds.....	19	74	309	891
Reptiles.....	4	25	187	619
Amphibians.....	2	12	23	135
Fish.....	4	11	20	86
Arthropods.....	4	5	6	Many
Mollusks.....	1	1	1	Many
Total.....	47	177	780	2,384+

ANIMALS IN THE COLLECTION ON JUNE 30, 1959

MAMMALS

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
MONOTREMATA		
Tachyglossidae:		
Echidna, or spiny anteater.....	<i>Tachyglossus aculeatus</i>	1
MARSUPIALIA		
Didelphidae:		
Opossum.....	<i>Didelphis marsupialis</i>	1
Dasyuridae:		
Tasmanian devil.....	<i>Sarcophilus harrisii</i>	2
Phalangeridae:		
Vulpine opossum.....	<i>Trichosurus vulpecula</i>	1
Lesser flying phalanger.....	<i>Petaurus norfolcensis</i>	3
Phascolomidae:		
Hairy-nosed wombat.....	<i>Lasiorhinus latifrons</i>	2
Mainland wombat.....	<i>Wombatus hirsutus</i>	1
Macropodidae:		
Red kangaroo.....	<i>Macropus rufus</i>	1
Rat kangaroo.....	<i>Hypsiprymnodon moschatus</i>	9
INSECTIVORA		
Erinaceidae:		
European hedgehog.....	<i>Erinaceus europaeus</i>	1
Soricidae:		
Short-tailed shrew.....	<i>Blarina brevicauda</i>	1
PRIMATES		
Lorisidae:		
Slow loris.....	<i>Nycticebus coucang</i>	1
Thick-tailed galago.....	<i>Galago crassicaudatus</i>	2
Cebidae:		
Night monkey.....	<i>Aotus trivirgatus</i>	6
Red uakari.....	<i>Cacajao rubicundus</i>	1
Brown capuchin monkey.....	<i>Cebus capucinus</i>	8
White-throated capuchin.....		
Capuchin monkey.....		
Squirrel monkey.....	<i>Saimiri sciureus</i>	7
Colombian black spider monkey.....	<i>Ateles fusciceps</i>	1
Spider monkey.....	<i>Ateles geoffroyi</i>	2
Woolly monkey.....	<i>Lagothrix pygmaea</i>	1
Callithricidae:		
Cottontop marmoset.....	<i>Callithrix jacchus</i>	3
Golden lion tamarin.....	<i>Leontocbus rosalia</i>	1
Black-and-red tamarin.....	<i>Saguinus nigricollis</i>	1
Cercopithecidae:		
Toque, or bonnet monkey.....	<i>Macaca sinica</i>	3
Pig-tailed monkey.....	<i>Macaca nemestrina</i>	1
Javan macaque.....	<i>Macaca irus</i>	1
Crab-eating macaque.....	<i>Macaca irus</i>	1
Philippine macaque.....	<i>Macaca philippinensis</i>	2

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Cercopithecidae—Continued		
Macaque, hybrid.....	<i>Macaca philippinensis</i> × <i>Macaca irus</i>	2
Rhesus monkey.....	<i>Macaca mulatta</i>	3
Chinese macaque.....	<i>Macaca lasiotis</i>	1
Formosan monkey.....	<i>Macaca cyclopis</i>	6
Red-faced macaque.....	<i>Macaca speciosa</i>	1
Barbary ape.....	<i>Macaca sylvanus</i>	11
Moor macaque.....	<i>Macaca maurus</i>	2
Gray-cheeked mangabey.....	<i>Cercocebus albigena</i>	1
Agile mangabey.....	<i>Cercocebus galeritus</i>	1
Golden-bellied mangabey.....	<i>Cercocebus galeritus</i>	1
Red-crowned mangabey.....	<i>Cercocebus torquatus</i>	2
Sooty mangabey.....	<i>Cercocebus fuliginosus</i>	5
Crested mangabey.....	<i>Cercocebus aterrimus</i>	2
Black-crested mangabey.....	<i>Cercocebus aterrimus</i>	3
Golden baboon.....	<i>Papio cynocephalus</i>	1
Hamadryas baboon.....	<i>Papio hamadryas</i>	1
Chacma baboon.....	<i>Papio comatus</i>	1
Mandrill.....	<i>Mandrillus sphinx</i>	1
Gelada baboon.....	<i>Theropithecus gelada</i>	1
Vervet guenon.....	<i>Cercopithecus aethiops</i>	1
Green guenon.....	<i>Cercopithecus aethiops</i>	2
Guenon, hybrid.....	<i>Cercopithecus aethiops</i> × <i>C. a. pygerythrus</i>	2
Moustached monkey.....	<i>Cercopithecus cephus</i>	2
Diana monkey.....	<i>Cercopithecus diana</i>	1
Roloway monkey.....	<i>Cercopithecus diana</i>	1
Preussi's guenon.....	<i>Cercopithecus lhoesti</i>	1
DeBrazza's guenon.....	<i>Cercopithecus neglectus</i>	2
White-nosed guenon.....	<i>Cercopithecus nictitans</i>	1
Lesser white-nosed guenon.....	<i>Cercopithecus nictitans</i>	1
Allen's monkey.....	<i>Allenopithecus nigroviridis</i>	2
Spectacled langur.....	<i>Presbytis phayrei</i>	1
Pongidae:		
Hoolock.....	<i>Hylobates hoolock</i>	1
White-handed gibbon.....	<i>Hylobates lar</i>	7
Wau-wau gibbon.....	<i>Hylobates moloch</i>	1
Gibbon, hybrid.....	<i>Hylobates agilis</i> × <i>H. lar</i>	1
Gibbon, hybrid.....	<i>Hylobates lar</i> × <i>H. sp.</i>	3
Sumatran orangutan.....	<i>Pongo pygmaeus</i>	2
Bornean orangutan.....	<i>Pongo pygmaeus</i>	1
Chimpanzee.....	<i>Pan satyrus</i>	4
Gorilla.....	<i>Gorilla gorilla</i>	2

EDENTATA

Myrmecophagidae:		
Giant anteater.....	<i>Myrmecophaga tridactyla</i>	1
Bradypodidae:		
Two-toed sloth.....	<i>Choloepus didactylus</i>	5

LAGOMORPHA

Leporidae:		
Domestic rabbit.....	<i>Oryctolagus cuniculus</i>	2

RODENTIA

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Sciuridae:		
Gray squirrel (black).....	<i>Sciurus carolinensis</i> , melanistic phase.	1
Gray squirrel (albino).....	<i>Sciurus carolinensis</i>	2
Fox squirrel.....	<i>Sciurus niger</i>	1
Giant Indian squirrel.....	<i>Ratufa indica</i>	4
Asiatic squirrel.....	<i>Callosciurus nigrovittatus</i>	1
Formosan tree squirrel.....	<i>Callosciurus erythraeus</i>	5
Asiatic forest squirrel.....	<i>Callosciurus caniceps</i>	4
Striped ground squirrel.....	<i>Lariscus insignis</i>	2
Long-nosed squirrel.....	<i>Dremomys rufigenis</i>	1
Woodchuck, or groundhog.....	<i>Marmota monax</i>	1
Prairie-dog.....	<i>Cynomys ludovicianus</i>	Many
White-tailed squirrel.....	<i>Citellus leucurus</i>	2
Eastern chipmunk.....	<i>Tamias striatus</i>	1
Eastern chipmunk, albino.....	<i>Tamias striatus</i>	1
Red-and-white flying squirrel.....	<i>Petaurista albirufus</i>	1
Formosan flying squirrel.....	<i>Petaurista grandis</i>	1
Eastern flying squirrel.....	<i>Glaucomys volans</i>	15
Cricetidae:		
Vesper rat.....	<i>Nyctomys sumichrasti</i>	2
Hamster.....	<i>Mesocricetus auratus</i>	3
Lesser Egyptian gerbil.....	<i>Gerbillus gerbillus</i>	1
Fat-tailed gerbil.....	<i>Pachyuromys duprasi</i>	19
Hairy-tailed jird.....	<i>Sekeetamys calurus</i>	1
Jird.....	<i>Meriones</i> sp.....	8
Muridae:		
Egyptian spiny mouse.....	<i>Acomys cahirinus</i>	24
Egyptian spiny mouse.....	<i>Acomys dimidiatus</i>	Many
Slender-tailed cloud rat.....	<i>Phloeomys cumingii</i>	3
Gliridae:		
African dormouse.....	<i>Graphiurus murinus</i>	1
Dipodidae:		
Lesser or desert jerboa.....	<i>Jaculus jaculus</i>	1
Four-toed jerboa.....	<i>Allactaga tetradactyla</i>	6
Hystriidae:		
Malay porcupine.....	<i>Acanthion brachyura</i>	1
African porcupine.....	<i>Hystrix galeata</i>	4
Erethizontidae:		
Prehensile-tailed porcupine.....	<i>Coendou prehensilis</i>	1
Caviidae:		
Guinea-pig.....	<i>Cavia porcellus</i>	30
Hydrochoeridae:		
Capybara.....	<i>Hydrochoerus hydrochoeris</i>	2
Dinomyidae:		
Red agouti.....	<i>Dinomys branickii</i>	2
Dasyproctidae:		
Agouti.....	<i>Dasyprocta prymnolopha</i>	1
Speckled agouti.....	<i>Dasyprocta punctata</i>	1
Chinchillidae:		
Peruvian viscaccia.....	<i>Lagidium viscaccia</i>	1
Chinchilla.....	<i>Chinchilla chinchilla</i>	2

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Capromyidae:		
Coypu.....	<i>Myocastor coypus</i>	1

CARNIVORA

Canidae:		
Dingo.....	<i>Canis antarcticus</i>	4
Timber wolf.....	<i>Canis lupus</i>	2
Texas red wolf.....	<i>Canis niger</i>	2
Red fox.....	<i>Vulpes fulva</i>	2
Platinum fox.....	<i>Vulpes fulva</i>	2
Fennec.....	<i>Fennecus zerda</i>	2
Gray fox.....	<i>Urocyon cinereoargenteus</i>	1
Raccoon dog.....	<i>Nyctereutes procyonoides</i>	1
Cape hunting dog.....	<i>Lycaon pictus</i>	4
Big-eared fox.....	<i>Otocyon megalotis</i>	3
Ursidae:		
Spectacled bear.....	<i>Tremarctos ornatus</i>	1
Himalayan bear.....	<i>Selenarctos thibetanus</i>	2
Japanese black bear.....	<i>Selenarctos thibetanus</i>	1
Korean bear.....	<i>Selenarctos thibetanus</i>	2
Black bear.....	<i>Euarctos americanus</i>	2
Alaskan brown bear.....	<i>Ursus sp.</i>	1
European brown bear.....	<i>Ursus arctos</i>	3
Iranian brown bear.....	<i>Ursus arctos</i>	2
Alaskan Peninsula bear.....	<i>Ursus gyas</i>	2
Grizzly bear.....	<i>Ursus horribilis</i>	3
Sitka brown bear.....	<i>Ursus sitkensis</i>	2
Polar bear.....	<i>Thalarctos maritimus</i>	2
Bear, hybrid.....	<i>Thalarctos maritimus</i> × <i>Ursus middendorffi</i>	6
Malay sun bear.....	<i>Helarctos malayanus</i>	3
Procyonidae:		
Raccoon.....	<i>Procyon lotor</i>	4
Red coatimundi.....	<i>Nasua nasua</i>	2
Coatimundi.....	<i>Nasua narica</i>	14
Kinkajou.....	<i>Potos flavus</i>	4
Olingo.....	<i>Bassaricyon gabbi</i>	2
Lesser panda.....	<i>Ailurus fulgens</i>	3
Mustelidae:		
Short-tailed weasel.....	<i>Mustela erminea</i>	1
Eastern weasel.....	<i>Mustela frenata</i>	1
Ferret, albino.....	<i>Mustela eversmanni</i>	1
Marten.....	<i>Martes americana</i>	1
Fisher.....	<i>Martes pennanti</i>	1
Tayra.....	<i>Tayra barbara</i>	1
Grison.....	<i>Galictis vittata</i>	1
Wolverine.....	<i>Gulo luscus</i>	1
American badger.....	<i>Taxidea taxus</i>	1
Golden-bellied badger.....	<i>Helictis moschata</i>	2
Common skunk.....	<i>Mephitis mephitis</i>	3
California spotted skunk.....	<i>Spilogale gracilis</i>	1
African small-clawed otter.....	<i>Lutra cinerea</i>	1
South American flat-tailed otter.....	<i>Pteronura brasiliensis</i>	1
Malayan small-clawed otter.....	<i>Amblonyx cinerea</i>	1

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Viverridae:		
Genet.....	<i>Genetta genetta</i>	5
Formosan spotted civet.....	<i>Viverricula indica</i>	2
Ground civet.....	<i>Viverra zangalunga</i>	1
Linsang.....	<i>Prionodon linsang</i>	1
Formosan masked civet.....	<i>Paguma larvata</i>	4
Binturong.....	<i>Arctictis binturong</i>	1
African gray mongoose.....	<i>Herpestes ichneumon</i>	1
Water civet.....	<i>Atilax poludinosus</i>	3
White-tailed civet.....	<i>Ichneumia albicauda</i>	2
Cryptoproctidae:		
Fossa.....	<i>Cryptoprocta ferox</i>	1
Hyaenidae:		
Spotted hyena.....	<i>Crocuta crocuta</i>	2
Striped hyena.....	<i>Hyaena hyaena</i>	2
Felidae:		
Jungle cat.....	<i>Felis chaus</i>	1
Pallas's cat.....	<i>Felis manul</i>	2
Serval cat.....	<i>Felis serval</i>	3
Ocelot.....	<i>Felis pardalis</i>	2
Margay cat.....	<i>Felis wiedii</i>	2
Pampas cat.....	<i>Felis pajeros</i>	1
Puma.....	<i>Felis concolor</i>	5
Lynx.....	<i>Lynx canadensis</i>	2
Bobcat.....	<i>Lynx rufus</i>	2
Leopard.....	<i>Panthera pardus</i>	4
Black leopard.....	<i>Panthera pardus</i>	2
Lion.....	<i>Panthera leo</i>	3
Bengal tiger.....	<i>Panthera tigris</i>	4
Jaguar.....	<i>Panthera onca</i>	1
Snow leopard.....	<i>Panthera uncia</i>	3
Cheetah.....	<i>Ocinonyx jubata</i>	2
PINNIPEDIA		
Otariidae:		
Sea-lion.....	<i>Zalophus californianus</i>	1
Patagonian sea-lion.....	<i>Otaria flavescens</i>	2
TUBULIDENTATA		
Orycteropodidae:		
Aardvark, or antbear.....	<i>Orycteropus afer</i>	1
PROBOSCIDEA		
Elephantidae:		
African elephant.....	<i>Loxodonta africana</i>	1
Indian elephant.....	<i>Elephas maximus</i>	3
PERISSODACTYLA		
Equidae:		
Mongolian wild horse.....	<i>Equus przewalskii</i>	1
Kiang, or Asiatic wild ass.....	<i>Equus kiang</i>	1
Burro, or donkey.....	<i>Equus asinus</i>	1
Grant's zebra.....	<i>Equus burchelli</i>	5
Grevy's zebra.....	<i>Equus grevyi</i>	3

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Tapiridae:		
Brazilian tapir	<i>Tapirus terrestris</i>	1
Rhinocerotidae:		
White, or square-lipped, rhinoceros	<i>Ceratotherium simum</i>	2
ARTIODACTYLA		
Tayassuidae:		
Collared peccary	<i>Pecari tajacu</i>	2
Hippopotamidae:		
Hippopotamus	<i>Hippopotamus amphibius</i>	5
Pygmy hippopotamus	<i>Choeropsis liberiensis</i>	3
Camelidae:		
Llama	<i>Lama glama</i>	9
Guanaco	<i>Lama guanicoe</i>	3
Alpaca	<i>Lama pacos</i>	4
Bactrian camel	<i>Camelus bactrianus</i>	2
Cervidae:		
Brown fallow deer	<i>Dama dama</i>	7
White fallow deer	<i>Dama dama</i>	6
Axis deer	<i>Axis axis</i>	4
Red deer	<i>Cervus elaphus</i>	7
American elk	<i>Cervus canadensis</i>	4
Sika deer	<i>Cervus nippon</i>	4
Père David's deer	<i>Elaphurus davidianus</i>	1
Virginia deer	<i>Odocoileus virginianus</i>	5
Costa Rican deer	<i>Odocoileus virginianus</i>	1
Reindeer	<i>Rangifer tarandus</i>	14
Forest caribou	<i>Rangifer caribou</i>	1
Giraffidae:		
Okapi	<i>Okapia johnstoni</i>	1
Nubian giraffe	<i>Giraffa camelopardalis</i>	4
Antilocapridae:		
Pronghorn	<i>Antilocapra americana</i>	5
Bovidae:		
Sitatunga	<i>Tragelaphus spekii</i>	2
Eland	<i>Taurotragus oryx</i>	2
Anoa	<i>Anoa depressicornis</i>	3
Zebu	<i>Bos indicus</i>	1
Yak	<i>Poephaqus grunniens</i>	2
Gaur	<i>Bibos gaurus</i>	4
African buffalo	<i>Syncerus caffer</i>	1
American bison	<i>Bison bison</i>	2
Wisent, or European bison	<i>Bison bonasus</i>	2
Black-fronted duiker	<i>Cephalophus nigrifrons</i>	1
Saiga antelope	<i>Saiga tatarica</i>	1
Rocky mountain goat	<i>Oreamnos americanus</i>	2
Tahr	<i>Hemitragus jemlahicus</i>	2
Ibex	<i>Capra ibex</i>	1
Blue sheep	<i>Pseudois nayaur</i>	1
Aoudad	<i>Ammotragus lervia</i>	3
Dall sheep	<i>Ovis dalli</i>	2
Mouflon	<i>Ovis musimon</i>	1

BIRDS

SPHENISCIFORMES

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Spheniscidae:		
King penguin.....	<i>Aptenodytes patagonica</i>	4
Adelie penguin.....	<i>Pygoscelis adeliae</i>	5

STRUTHIONIFORMES

Struthionidae:		
Ostrich.....	<i>Struthio camelus</i>	1

RHEIFORMES

Rheidae:		
Rhea.....	<i>Rhea americana</i>	1

CASUARIIFORMES

Dromiceidae:		
Emu.....	<i>Dromiceius novaehollandiae</i>	4

PROCELLARIIFORMES

Diomedidae:		
Black-footed albatross.....	<i>Diomedea nigripes</i>	2
Laysan albatross.....	<i>Diomedea immutabilis</i>	1

PELICANIFORMES

Phoenicopteridae:		
Chilean flamingo.....	<i>Phoenicopterus chilensis</i>	2
Cuban flamingo.....	<i>Phoenicopterus ruber</i>	2
Old World flamingo.....	<i>Phoenicopterus antiquorum</i>	1
Pelecanidae:		
Rose-colored pelican.....	<i>Pelecanus onocrotalus</i>	2
White pelican.....	<i>Pelecanus erythrorhynchus</i>	3
Brown pelican.....	<i>Pelecanus occidentalis</i>	1
Phalacrocoracidae:		
Double-crested cormorant.....	<i>Phalacrocorax auritus</i>	1
Anhingidae:		
Snakebird.....	<i>Anhinga anhinga</i>	2

CICONIIFORMES

Ardeidae:		
Great white heron.....	<i>Ardea occidentalis</i>	3
Louisiana heron.....	<i>Hydranassa tricolor</i>	4
American egret.....	<i>Casmerodius albus</i>	4
Snowy egret.....	<i>Leucophoyx thula</i>	2
Black-crowned night heron.....	<i>Nycticorax nycticorax</i>	7
Least bittern.....	<i>Ixobrychus exilis</i>	2
American egret.....	<i>Herodias egretta</i>	1
Tiger bittern.....	<i>Tigrisoma lineatum</i>	4
Cochleariidae:		
Boat-billed heron.....	<i>Cochlearius cochlearius</i>	1
Balaenicipitidae:		
Shoebill.....	<i>Balaeniceps rex</i>	1
Ciconiidae:		
Marabou stork.....	<i>Leptoptilos crumeniferus</i>	1
Lesser adjutant.....	<i>Leptoptilos javanicus</i>	1

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Threskiornithidae:		
Glossy ibis.....	<i>Plegadis falcinellus</i>	2
Eastern glossy ibis.....	<i>Plegadis falcinellus</i>	2
Black-headed ibis.....	<i>Threskiornis melanocephala</i>	1
Roseate spoonbill.....	<i>Ajaia ajaja</i>	2
White ibis.....	<i>Eudocimus albus</i>	2
Scarlet ibis.....	<i>Eudocimus ruber</i>	2

ANSERIFORMES

Anhimidae:		
Crested screamer.....	<i>Chauna torquata</i>	4
Anatidae:		
Mute swan.....	<i>Cygnus olor</i>	2
Whooper swan.....	<i>Olor cygnus</i>	2
Whistling swan.....	<i>Olor columbianus</i>	4
Trumpeter swan.....	<i>Olor buccinator</i>	2
Cape Barren goose.....	<i>Cereopsis novaehollandiae</i>	1
Australian pied goose.....	<i>Anseranas semipalmata</i>	1
Black swan.....	<i>Chenopsis atrata</i>	3
Blue goose.....	<i>Chen caerulescens</i>	6
Lesser snow goose.....	<i>Chen hyperborea</i>	2
Greater snow goose.....	<i>Chen atlantica</i>	6
Ross's goose.....	<i>Chen rossii</i>	4
Indian bar-headed goose.....	<i>Eulabeia indica</i>	5
White-fronted goose.....	<i>Anser albifrons</i>	3
Emperor goose.....	<i>Philacte canagica</i>	2
Canada goose.....	<i>Branta canadensis</i>	34
Lesser Canada goose.....		
Cackling goose.....		
White-cheeked goose.....		
Upland goose.....	<i>Chloephaga leucoptera</i>	1
Canada goose X Blue goose, hybrid.....	<i>Branta canadensis</i> X <i>Chen caerulescens</i>	2
Black-bellied tree duck.....	<i>Dendrocygna autumnalis</i>	8
Fulvous tree duck.....	<i>Dendrocygna bicolor</i>	2
Comb duck.....	<i>Sarkidiornis melanota</i>	1
European shell duck.....	<i>Tadorna tadorna</i>	1
Mallard duck, albino.....	<i>Anas platyrhynchos</i>	1
Mallard duck.....	<i>Anas platyrhynchos</i>	26
Mallard duck X American pintail duck, hybrid.....	<i>Anas platyrhynchos</i> X <i>Anas acuta</i>	1
Indian spotted-bill duck.....	<i>Anas poecilorhyncha</i>	1
Black duck.....	<i>Anas rubripes</i>	2
Pintail duck.....	<i>Anas acuta</i>	1
Baldpate.....	<i>Mareca americana</i>	13
Wood duck.....	<i>Aix sponsa</i>	34
Wood duck X Red-headed duck, hybrid.....	<i>Aix sponsa</i> X <i>Aythya americana</i>	1
Mandarin duck.....	<i>Dendronessa galericulata</i>	29
Rosy-billed pochard.....	<i>Metopiana peposaca</i>	1
Red-crested pochard.....	<i>Netta rufina</i>	1
Canvasback duck.....	<i>Aythya valisineria</i>	9
Red-headed duck.....	<i>Aythya americana</i>	11

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Anatidae—Continued		
Greater scaup duck.....	<i>Aythya marila</i>	10
Lesser scaup duck.....	<i>Aythya affinis</i>	7

FALCONIFORMES

Cathartidae:		
Andean condor.....	<i>Vultur gryphus</i>	1
King vulture.....	<i>Sarcoramphus papa</i>	1
Black vulture.....	<i>Coragyps atratus</i>	1
Turkey vulture.....	<i>Cathartes aura</i>	1
Sagittariidae:		
Secretarybird.....	<i>Sagittarius serpentarius</i>	2
Accipitridae:		
Cayenne kite.....	<i>Odontorhynchus palliatus</i>	1
African yellow-billed kite.....	<i>Milvus migrans</i>	2
Brahminy kite.....	<i>Haliastur indus</i>	1
Buzzard eagle.....	<i>Buteo poecilochrous</i>	1
Red-tailed hawk.....	<i>Buteo jamaicensis</i>	5
Swainson's hawk.....	<i>Buteo swainsoni</i>	1
Black-faced hawk.....	<i>Leucopternis melanops</i>	1
Guianan crested eagle.....	<i>Morphnus guianensis</i>	1
Harpy eagle.....	<i>Harpia harpyja</i>	1
Golden eagle.....	<i>Aquila chrysaetos</i>	1
Monkey-eating eagle.....	<i>Pithecophaga jefferyi</i>	1
Bald eagle.....	<i>Haliaeetus leucocephalus</i>	7
Ruppell's vulture.....	<i>Gyps rueppellii</i>	2
White-backed vulture.....	<i>Pseudogyps africanus</i>	1
Bateleur eagle.....	<i>Terathopus ecaudatus</i>	3
Falconidae:		
Forest falcon.....	<i>Micrastur semitorquatus</i>	2
Chimango.....	<i>Milvago chimango</i>	2
South American caracara.....	<i>Polyborus plancus</i>	3
Audubon's caracara.....	<i>Polyborus cheriway</i>	1
Sparrow hawk.....	<i>Falco sparverius</i>	6

GALLIFORMES

Megapodiidae:		
Brush turkey.....	<i>Alectura lathami</i>	1
Cracidae:		
Nocturnal curassow.....	<i>Nothocrax urumutum</i>	1
White-headed piping guan.....	<i>Pipile cumanensis</i>	1
Blue-cered curassow.....	<i>Craz alberti</i>	2
Wattled curassow.....	<i>Craz globulosa</i>	2
Panama curassow.....	<i>Craz panamensis</i>	1
Phasianidae:		
Erckel's francolin.....	<i>Francolinus erckeli</i>	5
Hildebrandt's francolin.....	<i>Francolinus hildebrandti</i>	1
Bobwhite.....	<i>Colinus virginianus</i>	1
Hungarian partridge.....	<i>Perdix perdix</i>	2
Japanese quail.....	<i>Coturnix coturnix</i>	1
Nepal pheasant.....	<i>Gennaeus leucomelanus</i>	2
Swinhoe's pheasant.....	<i>Gennaeus swinhoi</i>	1
Red junglefowl.....	<i>Gallus gallus</i>	9

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Phasianidae—Continued		
Ring-necked pheasant.....	<i>Phasianus colchicus</i>	4
Ring-necked pheasant, albino.....	<i>Phasianus colchicus</i>	1
Reeves's pheasant.....	<i>Symaticus reevesi</i>	2
Lady Amherst pheasant.....	<i>Chrysolophus amherstiae</i>	1
Golden pheasant.....	<i>Chrysolophus pictus</i>	5
Peafowl.....	<i>Pavo cristatus</i>	13
Argus pheasant.....	<i>Argusianus argus</i>	2
Numididae:		
Vulturine guineafowl.....	<i>Acryllium vulturinum</i>	5
Meleagrididae:		
Ocellated turkey.....	<i>Agriocharis ocellata</i>	1
Wild turkey.....	<i>Meleagris gallopavo</i>	11
Gruidae:		
Siberian crane.....	<i>Grus leucogeranus</i>	1
Demoiselle crane.....	<i>Anthropoides virgo</i>	1
Psophiidae:		
Trumpeter.....	<i>Psophia crepitans</i>	2
Rallidae:		
Virginia rail.....	<i>Lallus limicola</i>	1
Black-and-white crake.....	<i>Laterallus leucopyrrhus</i>	1
South Pacific swampheu.....	<i>Borphyrio poliocephalus</i>	1
American coot.....	<i>Fulica americana</i>	1
Eurypygidae:		
Sun bittern.....	<i>Eurypyga helias</i>	2
Cariamidae:		
Cariama or seriama.....	<i>Cariama cristata</i>	1

CHARADRIIFORMES

Jacanidae:		
Common jacana.....	<i>Jacana spinosa</i>	3
Haematopodidae:		
Oystercatcher.....	<i>Haematopus ostralegus</i>	2
Stercorariidae:		
MacCormack's skua.....	<i>Catharacta maccormacki</i>	4
Charadriidae:		
Australian banded plover.....	<i>Zonifer tricolor</i>	6
South American lapwing.....	<i>Belonopterus cayennensis</i>	1
Killdeer.....	<i>Charadrius vociferus</i>	1
Recurvirostridae:		
Black-necked stilt.....	<i>Himantopus mexicanus</i>	1
Burhinidae:		
South American thick-knee.....	<i>Burhinus bistriatus</i>	1
Laridae:		
Ring-billed gull.....	<i>Larus delawarensis</i>	2
Kelp gull.....	<i>Larus dominicanus</i>	2
Laughing gull.....	<i>Larus atricilla</i>	1
Silver gull.....	<i>Larus novaeollandiae</i>	12

COLUMBIFORMES

Columbidae:		
Homing pigeon.....	<i>Columba livia</i>	1
Band-tailed pigeon.....	<i>Columba fasciata</i>	2

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Columbidae—Continued		
Black-billed pigeon.....	<i>Columba nigrirostris</i>	1
Mourning dove.....	<i>Zenaidura macroura</i>	3
White-winged dove.....	<i>Zenaida asiatica</i>	1
Ring-necked dove.....	<i>Streptopelia decaocto</i>	7
Blue-headed ring dove.....	<i>Streptopelia tranquebarica</i>	2
Diamond dove.....	<i>Geopelia cuneata</i>	1
Ground dove.....	<i>Columbigallina passerina</i>	5
Plain-breasted ground dove.....	<i>Columbigallina minuta</i>	7
Bleeding-heart dove.....	<i>Gallicolumba luzonica</i>	2
Crowned pigeon.....	<i>Goura victoria</i>	2

PSITTACIFORMES

Psittacidae:

Kea parrot.....	<i>Nestor notabilis</i>	2
Red lory.....	<i>Domicella garrula</i>	1
Banksian cockatoo.....	<i>Calyptorhynchus magnificus</i>	1
White cockatoo.....	<i>Kakatoe alba</i>	2
Solomon Islands cockatoo.....	<i>Kakatoe ducrops</i>	1
Sulphur-crested cockatoo.....	<i>Kakatoe galerita</i>	5
Bare-eyed cockatoo.....	<i>Kakatoe sanguinea</i>	5
Great red-crested cockatoo.....	<i>Kakatoe moluccensis</i>	1
Leadbeater's cockatoo.....	<i>Kakatoe leadbeateri</i>	7
Cockatiel.....	<i>Nymphicus hollandicus</i>	3
Yellow-and-blue macaw.....	<i>Ara arauruna</i>	3
Red-and-blue macaw.....	<i>Ara chloroptera</i>	2
Red-blue-and-yellow macaw.....	<i>Ara macao</i>	2
Petz's parakeet.....	<i>Aratinga canicularis</i>	1
Rusty-cheeked parrot.....	<i>Aratinga pertinax</i>	2
White-winged parakeet.....	<i>Brotogeris versicolurus</i>	1
Yellow-naped parrot.....	<i>Amazona auropalliata</i>	4
Finsch's parrot.....	<i>Amazona finschi</i>	1
Red-fronted parrot.....	<i>Amazona bodini</i>	1
Double yellow-headed parrot.....	<i>Amazona oratrix</i>	3
Red-shouldered parakeet.....	<i>Psittacula eupatria</i>	1
Moustached parakeet.....	<i>Psittacula fasciata</i>	1
Barraband's parakeet.....	<i>Polytelis swainsoni</i>	1
Rosy-faced lovebird.....	<i>Agapornis roseicollis</i>	1
Fischer's lovebird.....	<i>Agapornis fischeri</i>	1
Masked lovebird.....	<i>Agapornis personata</i>	4
Grass parakeet, or budgerigar.....	<i>Melopsittacus undulatus</i>	Many

CUCULIFORMES

Musophagidae:

Purple turaco.....	<i>Tauraco persa</i>	1
South African turaco.....	<i>Tauraco corythaix</i>	1
Plantain-eater.....	<i>Crinifer africanus</i>	1
White-bellied go-away-bird.....	<i>Corythaixoides leucogaster</i>	1

Cuculidae:

Koel.....	<i>Eudynamys scolopacea</i>	1
Roadrunner.....	<i>Geococcyx californianus</i>	1

STRIGIFORMES

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Tytonidae:		
Barn owl.....	<i>Tyto alba</i>	1
Strigidae:		
Screech owl.....	<i>Otus asio</i>	2
Great horned owl.....	<i>Bubo virginianus</i>	5
Colombian great horned owl.....	<i>Bubo virginianus</i>	1
Spectacled owl.....	<i>Pulsatrix perspicillata</i>	1
Malay fishing owl.....	<i>Ketupa ketupu</i>	2
Snowy owl.....	<i>Nyctea nyctea</i>	3
Barred owl.....	<i>Strix varia</i>	10

COLIIFORMES

Coliidae:		
Mousebird.....	<i>Colius striatus</i>	2

CORACIIFORMES

Alcedinidae:		
Kookaburra.....	<i>Dacelo gigas</i>	3
Momotidae:		
Motmot.....	<i>Momotus lessoni</i>	1
Coraciidae:		
Lilac-breasted roller.....	<i>Coracias caudata</i>	3
Indian roller.....	<i>Coracias benghalensis</i>	2
Bucerotidae:		
Gray hornbill.....	<i>Tockus birostris</i>	2
Wreathed hornbill.....	<i>Aceros plicatus</i>	1
Pied hornbill.....	<i>Anthracoceros malabaricus</i>	1
Black-and-white casqued hornbill.....	<i>Bycanistes subcylindricus</i>	2
Black casqued hornbill.....	<i>Ceratogymna atrata</i>	2
Philippine hornbill.....	<i>Buceros hydrocorax</i>	1
Abyssinian ground hornbill.....	<i>Bucorvus abyssinicus</i>	1

PICIFORMES

Capitonidae:		
Asiatic great barbet.....	<i>Megalaima virens</i>	1
Asiatic red-fronted barbet.....	<i>Megalaima asiatica</i>	1
Toucan barbet.....	<i>Semnornis ramphastinus</i>	2
Ramphastidae:		
White-lined toucanet.....	<i>Aulacorhynchus albivittatus</i>	3
White-breasted toucan.....	<i>Ramphastos culminatus</i>	1
Sulphur-breasted toucan.....	<i>Ramphastos carinatus</i>	3
Swainson's toucan.....	<i>Ramphastos swainsoni</i>	1
Toco toucan.....	<i>Ramphastos toco</i>	1
Picidae:		
Scaly-bellied woodpecker.....	<i>Picus squamatus</i>	2
Golden-backed woodpecker.....	<i>Brachypternus benghalensis</i>	2

PASSERIFORMES

Cotingidae:		
Naked-throated bellbird.....	<i>Chasmorhynchus nudicollis</i>	1
Orange cock-of-the-rock.....	<i>Rupicola rupicola</i>	1
Scarlet cock-of-the-rock.....	<i>Rupicola sanguinolenta</i>	1

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Pipridae:		
Long-tailed manakin.....	<i>Chiroxiphia linearis</i>	2
Tyrannidae:		
Kiskadee flycatcher.....	<i>Pitangus sulphuratus</i>	1
Pittidae:		
Indian pitta.....	<i>Pitta brachyura</i>	2
Alaudidae:		
Skylark.....	<i>Alauda arvensis</i>	1
Corvidae:		
Steller's jay.....	<i>Cyanocitta stelleri</i>	4
Magpie.....	<i>Pica pica</i>	7
Yellow-billed magpie.....	<i>Pica nuttalli</i>	1
Hunting crow.....	<i>Kitta chinensis</i>	1
Formosan red-billed pie.....	<i>Kitta caerulea</i>	9
Asiatic tree pie.....	<i>Crypsirina formosae</i>	2
Raven.....	<i>Corvus corax</i>	1
African white-neck crow.....	<i>Corvus albus</i>	2
Crow.....	<i>Corvus brachyrhynchos</i>	2
Indian crow.....	<i>Corvus insolens</i>	2
Inca jay.....	<i>Xanthoura yncas</i>	2
Cracticidae:		
White-backed piping crow.....	<i>Gymnorhina hypoleuca</i>	1
Paridae:		
Great tit.....	<i>Parus major</i>	1
Gray tit.....	<i>Parus major</i>	3
Red-headed tit.....	<i>Aegithaliscus concinnus</i>	2
Ptilonorhynchidae:		
Satin bowerbird.....	<i>Ptilonorhynchus violaceus</i>	2
Timaliidae:		
Tit babbler.....	<i>Yuhina flavicollis</i>	3
Indian scimitar babbler.....	<i>Pomatorhinus horsfieldii</i>	1
Rusty-cheeked scimitar babbler.....	<i>Pomatorhinus erythrogenys</i>	1
Black-headed sibia.....	<i>Heterophasia capistrata</i>	3
Sittidae:		
Chestnut-bellied nuthatch.....	<i>Sitta castanea</i>	4
Pycnonotidae:		
Red-vented bulbul.....	<i>Pycnonotus cafer</i>	1
White-cheeked bulbul.....	<i>Pycnonotus leucogenys</i>	2
Brown-eared bulbul.....	<i>Molpastes leucostis</i>	3
Turdidae:		
Bonaparte's thrush.....	<i>Turdus grayi</i>	1
Robin, albino.....	<i>Turdus migratorius</i>	1
Cliff chat.....	<i>Thamnolaea cinnamomeiventris</i>	2
Silver-eared me-sia.....	<i>Mesia argentauris</i>	4
Muscicapidae:		
Veriter flycatcher.....	<i>Muscicapa thalassina</i>	3
Sturnidae:		
Jungle mynah.....	<i>Acridotheres tristis</i>	1
Burchell's glossy starling.....	<i>Lamprocolius purpureus</i>	3
Tri-colored starling.....	<i>Spreo superbus</i>	1
Long-tailed glossy starling.....	<i>Lamprotornis caudatus</i>	1
Gray-headed mynah.....	<i>Sturnus malabaricus</i>	1
Starling.....	<i>Sturnus vulgaris</i>	1

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Sturnidae—Continued		
Rose-colored pastor.....	<i>Pastor roseus</i>	1
Lesser hill mynah.....	<i>Gracula religiosa</i>	2
Greater hill mynah.....	<i>Gracula religiosa</i>	3
Parulidae:		
Ovenbird.....	<i>Seiurus aurocapillus</i>	1
Ploceidae:		
Baya weaver.....	<i>Ploceus baya</i>	5
Vitelline masked weaver.....	<i>Ploceus vitellinus</i>	3
Red bishop weaver.....	<i>Euplectes orix</i>	2
Yellow-crowned bishop weaver.....	<i>Euplectes afra</i>	4
Giant whydah.....	<i>Diatropura procne</i>	2
Mahali weaver.....	<i>Ploceipasser mahali</i>	1
Java finch.....	<i>Padda oryzivora</i>	14
Cut-throat weaver finch.....	<i>Amadina fasciata</i>	2
White-headed nun.....	<i>Lonchura maja</i>	7
Lavender finch.....	<i>Estrilda coerulescens</i>	2
Red-eared waxbill.....	<i>Estrilda estrild</i>	1
Common waxbill.....	<i>Estrilda troglodytes</i>	2
Strawberry finch.....	<i>Estrilda amandava</i>	8
Zebra finch.....	<i>Poephila castanotis</i>	20
Gouldian finch.....	<i>Poephila gouldiae</i>	1
Nectariniidae:		
Variable sunbird.....	<i>Cinnyris venustus</i>	2
Beautiful sunbird.....	<i>Nectarinia pulchella</i>	2
Scarlet-chested sunbird.....	<i>Chalcomitra rubescens</i>	2
Golden-winged sunbird.....	<i>Drepanorhynchus reichenowii</i>	2
Zosteropidae:		
White-eye.....	<i>Zosterops palpebrosa</i>	3
Coerebidae:		
Blue honeycreeper.....	<i>Cyanerpes cyaneus</i>	2
Icteridae:		
Rice grackle.....	<i>Psomocolax oryzivora</i>	1
Boat-tailed grackle.....	<i>Cassidix mexicanus</i>	5
Swainson's grackle.....	<i>Holotrisacus lugubris</i>	2
Shiny cowbird.....	<i>Molothrus bonariensis</i>	4
Red-breasted marshbird.....	<i>Leistes militaris</i>	4
Colombian red-eyed cowbird.....	<i>Tangavius armenti</i>	1
Purple grackle.....	<i>Quiscalus quiscula</i>	1
Giraud's oriole.....	<i>Icterus giraudi</i>	1
Troupial.....	<i>Icterus icterus</i>	1
Yellow-headed marshbird.....	<i>Agelaius icterocephalus</i>	1
Thraupidae:		
Crimson tanager.....	<i>Ramphocelus dimidiatus</i>	1
Yellow-rumped tanager.....	<i>Ramphocelus icteronotus</i>	3
Passerini's tanager.....	<i>Ramphocelus passerinii</i>	1
Black-and-white tanager.....	<i>Cissopis leveriana</i>	2
Fringillidae:		
Buff-throated saltator.....	<i>Saltator maximus</i>	1
Black-throated cardinal.....	<i>Paroaria gularis</i>	3
Brazilian cardinal.....	<i>Paroaria cucullata</i>	1
Dickcissel.....	<i>Spiza americana</i>	7
Evening grosbeak.....	<i>Hesperiphona vespertina</i>	2

Family and common name	Scientific name	Number
Fringillidae—Continued		
Tawny-bellied seedeater.....	<i>Sporophila minuta</i>	5
European goldfinch X Canary, hybrid.	<i>Carduelis carduelis</i> X <i>Serinus canarius</i> .	1
Song sparrow.....	<i>Melospiza melodia</i>	1
Black-throated cardinal.....	<i>Paroaria gularis</i>	1
Melodious grassquit.....	<i>Tiaris canora</i>	6
Rice grosbeak.....	<i>Oryzoborus crassirostris</i>	1
Lesser yellow finch.....	<i>Sicalis luteola</i>	3

REPTILES

LORICATA

Crocodylidae:

African crocodile.....	<i>Crocodylus niloticus</i>	2
Broad-nosed crocodile.....	<i>Osteolaemus tetraspis</i>	2
Narrow-nosed crocodile.....	<i>Crocodylus cataphractus</i>	1
Salt-water crocodile.....	<i>Crocodylus porosus</i>	1
American crocodile.....	<i>Crocodylus acutus</i>	2
Alligator.....	<i>Alligator mississippiensis</i>	16
Chinese alligator.....	<i>Alligator sinensis</i>	2
Caiman.....	<i>Caiman sclerops</i>	9
Gavial.....	<i>Tomistoma schlegeli</i>	1

SAURIA

Gekkonidae:

House gecko.....	<i>Gecko monarchus</i>	2
Gecko.....	<i>Tarentola mauritanica</i>	1
Giant gecko.....	<i>Gecko smithi</i>	1
Giant gecko.....	<i>Gecko stentor</i>	1

Agamidae:

Forest lizard.....	<i>Gonocephalus borneensis</i>	1
Forest lizard.....	<i>Gonocephalus grandis</i>	1
Flying lizard.....	<i>Draco quinquefasciata</i>	1

Chamaeleonidae:

Meller's chameleon.....	<i>Chamaeleo melleri</i>	3
Flap-necked chameleon.....	<i>Chamaeleo dilepis</i>	10

Iguanidae:

Common iguana.....	<i>Iguana iguana</i>	3
Carolina anole.....	<i>Anolis carolinensis</i>	Many
Giant anole.....	<i>Anolis equestris</i>	1
Texas horned lizard.....	<i>Phrynosoma cornutum</i>	12
Western horned lizard.....	<i>Phrynosoma cornutum</i>	2
Fence lizard.....	<i>Sceloporus undulatus</i>	3
Spiny-tailed iguana.....	<i>Ctenosaurus nigra</i>	1
Desert iguana.....	<i>Dipsosaurus dorsalis</i>	1
Sonora spiny lizard.....	<i>Sceloporus clarki</i>	2
Southern prairie lizard.....	<i>Sceloporus undulatus</i>	1
Pine lizard.....	<i>Sceloporus undulatus</i>	2
Crevice spiny lizard.....	<i>Sceloporus poinsetti</i>	2
Leopard lizard.....	<i>Crotaphytus wislizeni</i>	2
Collared lizard.....	<i>Crotaphytus collaris</i>	1
Western earless lizard.....	<i>Holbrookia maculata</i>	2
Ameiva lizard.....	<i>Ameiva ameiva</i>	1
British Guiana green lizard.....	<i>Centropyx striatus</i>	1

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Scincidae:		
Mourning skink.....	<i>Egernia luctuosa</i>	2
White's skink.....	<i>Egernia whitei</i>	8
Greater five-lined skink.....	<i>Eumeces fasciatus</i>	6
Great Plains skink.....	<i>Eumeces obsoletus</i>	1
Four-lined skink.....	<i>Eumeces tetragrammus</i>	2
Sand skink.....	<i>Scincus officinalis</i>	7
Stump-tailed lizard.....	<i>Trachysaurus rugosus</i>	1
Ground skink.....	<i>Lygosoma laterale</i>	2
Malayan skink.....	<i>Mabuya multifasciata</i>	7
Gerrhosauridae:		
Plated lizard.....	<i>Gerrhosaurus major</i>	4
Teiidae:		
Black tegu.....	<i>Tupinambis nigropunctatus</i>	1
Yellow tegu.....	<i>Tupinambis teguixin</i>	2
Lacertidae:		
European green lizard.....	<i>Lacerta viridis</i>	1
Anguidae:		
Glass lizard.....	<i>Ophisaurus ventralis</i>	3
Southern alligator lizard.....	<i>Gerrhonotus multicarinatus</i>	1
Alligator lizard.....	<i>Gerrhonotus multicarinatus</i>	1
Helodermatidae:		
Mexican beaded lizard.....	<i>Heloderma horridum</i>	3
Beaded lizard (black phase).....	<i>Heloderma horridum</i>	1
Gila monster.....	<i>Heloderma suspectum</i>	3
Varanidae:		
Bornean rough-necked monitor lizard.....	<i>Varanus nudicollis</i>	2
Indian monitor lizard.....	<i>Varanus flavescens</i>	1
Indian monitor lizard.....	<i>Varanus salvator</i>	1
Australian lace monitor.....	<i>Varanus varius</i>	2
Cape monitor.....	<i>Varanus albigularis</i>	1

SERPENTES

Boidae:		
Anaconda.....	<i>Eunectes murinus</i>	1
Bahama boa.....	<i>Epicrates striatus</i>	2
Rainbow boa.....	<i>Epicrates cenchria</i>	2
Cuban tree boa.....	<i>Epicrates angulifer</i>	5
Tree boa.....	<i>Boa enydris</i>	1
Cook's tree boa.....	<i>Boa enydris</i>	19
Ball python.....	<i>Python regius</i>	4
African python.....	<i>Python sebae</i>	1
Indian rock python.....	<i>Python molurus</i>	2
Regal python.....	<i>Python reticulatus</i>	2
Emperor boa.....	<i>Constrictor imperator</i>	1
Acrochordidae:		
Elephant trunk snake.....	<i>Acrochordus javanicus</i>	1
Colubridae:		
Slate water snake.....	<i>Enhydryis plumbea</i>	10
Flying snake.....	<i>Chrysopelea ornata</i>	1
Vine snake.....	<i>Oxybelis acuminatus</i>	1
Twig, or vine, snake.....	<i>Thelotornis kirklandi</i>	3
Mud snake.....	<i>Farancia abacura</i>	2

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Colubridae—Continued		
King snake.....	<i>Lampropeltis getulus</i>	3
Speckled king snake.....	<i>Lampropeltis getulus</i>	3
California king snake.....	<i>Lampropeltis getulus</i>	2
Florida king snake.....	<i>Lampropeltis getulus</i>	2
Sonoran king snake.....	<i>Lampropeltis getulus</i>	1
Scarlet king snake.....	<i>Lampropeltis doliata</i>	1
Milk snake.....	<i>Lampropeltis triangulum</i>	2
Mole snake.....	<i>Lampropeltis rhombomaculata</i>	1
Tropical king snake.....	<i>Lampropeltis polyzonus</i>	1
Garter snake.....	<i>Thamnophis sirtalis</i>	8
Lake Erie garter snake.....	<i>Thamnophis sirtalis</i>	1
Eastern hognose snake.....	<i>Heterodon platyrhinos</i>	1
Western hognose snake.....	<i>Heterodon nasicus</i>	2
Green snake.....	<i>Opheodrys aestivus</i>	1
Water snake.....	<i>Natrix sipedon</i>	5
Diamond-backed water snake.....	<i>Natrix rhombifera</i>	1
Brown water snake.....	<i>Natrix taxispilota</i>	1
Red-bellied water snake.....	<i>Natrix erythrogaster</i>	1
Florida water snake.....	<i>Natrix pictiventris</i>	4
Tessellated snake.....	<i>Natrix tessellatus</i>	1
Island water snake.....	<i>Natrix insularum</i>	1
Mangrove snake.....	<i>Natrix compressicauda</i>	2
Indigo snake.....	<i>Drymarchon corais</i>	1
Texas indigo snake.....	<i>Drymarchon corais</i>	1
Pilot black snake, albino.....	<i>Elaphe obsoleta</i>	1
Pilot black snake.....	<i>Elaphe obsoleta</i>	7
Southern pilot black snake.....	<i>Elaphe obsoleta</i>	1
Corn snake.....	<i>Elaphe obsoleta</i>	1
Lindheimer's rat snake.....	<i>Elaphe obsoleta</i>	1
Chicken snake.....	<i>Elaphe quadrivittata</i>	6
Aesculapian snake.....	<i>Elaphe longissima</i>	1
Black racer.....	<i>Coluber constrictor</i>	1
Red racer.....	<i>Masticophis flagellum</i>	1
Western coachwhip snake.....	<i>Masticophis flagellum</i>	2
Asiatic rat snake.....	<i>Elaphe taeniura</i>	3
Lesser Indian rat snake.....	<i>Elaphe carinata</i>	4
African house snake, or musaga.....	<i>Boaedon lineatum</i>	2
Ring-necked snake.....	<i>Diadophis punctatus</i>	2
DeKay's snake.....	<i>Storeria dekayi</i>	2
Grass green whip snake.....	<i>Dryophis prasinus</i>	1
Dhaman, or Greater Indian rat snake.....	<i>Ptyas mucosus</i>	9
File snake.....	<i>Simocephalus capensis</i>	1
Elapidae:		
Boomsnang.....	<i>Dispholidus typhus</i>	3
Indian cobra.....	<i>Naja naja</i>	4
Taiwan cobra.....	<i>Naja naja</i>	14
Black cobra.....	<i>Naja melanoleuca</i>	1
Egyptian cobra.....	<i>Naja haje</i>	2
King cobra.....	<i>Ophiophagus hannah</i>	1
Krait.....	<i>Bungarus multicinctus</i>	6

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Crotalidae:		
Northern copperhead.....	<i>Ancistrodon contortrix</i>	5
Broad-banded copperhead.....	<i>Ancistrodon contortrix</i>	1
Water moccasin, or cottonmouth.....	<i>Ancistrodon piscivorus</i>	4
Cantil.....	<i>Ancistrodon bilineatus</i>	2
Asian snorkel viper.....	<i>Ancistrodon acutus</i>	3
Palm viper.....	<i>Trimeresurus stejnegeri</i>	15
Pope's pit viper.....	<i>Trimeresurus popeorum</i>	1
Wagler's pit viper.....	<i>Trimeresurus wagleri</i>	1
Mamushi, or Asiatic viper.....	<i>Trimeresurus elegans</i>	3
Habu, or Asiatic viper.....	<i>Trimeresurus flavoviridis</i>	1
Eastern diamondback rattlesnake.....	<i>Crotalus adamanteus</i>	3
Western diamondback rattlesnake.....	<i>Crotalus atrox</i>	2
Viperidae:		
Puff adder.....	<i>Bitis arietans</i>	4
CHELONIA		
Chelydridae:		
Snapping turtle.....	<i>Chelydra serpentina</i>	21
Alligator snapping turtle.....	<i>Macrochelys temminckii</i>	5
Kinosternidae:		
Musk turtle.....	<i>Sternotherus odoratus</i>	4
Mud turtle.....	<i>Kinosternon subrubrum</i>	7
South American mud turtle.....	<i>Kinosternon cruentatum</i>	3
Emydidae:		
Spotted turtle.....	<i>Clemmys guttata</i>	4
Wood turtle.....	<i>Clemmys insculpta</i>	5
Pacific pond turtle.....	<i>Clemmys marmorata</i>	1
Kura kura box turtle.....	<i>Cuora amboinensis</i>	3
European pond turtle.....	<i>Emys orbicularis</i>	3
Box turtle.....	<i>Terrapene carolina</i>	Many
Three-toed box turtle.....	<i>Terrapene carolina</i>	3
Western box turtle.....	<i>Terrapene ornata</i>	2
Florida box turtle.....	<i>Terrapene bauri</i>	1
Diamondback turtle.....	<i>Malaclemys terrapin</i>	7
Map turtle.....	<i>Graptemys geographica</i>	3
Barbour's turtle.....	<i>Graptemys barbouri</i>	6
False map turtle.....	<i>Graptemys pseudogeographica</i>	4
Painted turtle.....	<i>Chrysemys picta</i>	Many
South American red-lined turtle.....	<i>Pseudemys callirostris</i>	Many
South American turtle.....	<i>Pseudemys dorbigni</i>	8
Cumberland turtle.....	<i>Pseudemys scripta</i>	22
Mobile turtle, or cooter.....	<i>Pseudemys floridana</i>	12
Florida water turtle, or cooter.....	<i>Pseudemys floridana</i>	15
Red-bellied turtle.....	<i>Pseudemys rubriventris</i>	11
Central American turtle.....	<i>Pseudemys ornata</i>	2
Cuban water turtle.....	<i>Pseudemys decussata</i>	1
Yellow-bellied turtle.....	<i>Pseudemys scripta</i>	13
Indian fresh-water turtle.....	<i>Batagur baska</i>	1
Reeves's turtle.....	<i>Chinemys reevesii</i>	5
Testudinidae:		
Giant Aldabra turtle.....	<i>Testudo elephantina</i>	2
Duncan Island turtle.....	<i>Testudo ephippium</i>	2

Family and common name	Scientific name	Number
Testudinidae—Continued		
South American turtle.....	<i>Testudo tabulata</i>	1
Galápagos turtle.....	<i>Testudo vicina</i>	1
African soft-shelled tortoise.....	<i>Malacochersus tornieri</i>	2
Hinged-backed turtle.....	<i>Kinixys erosa</i>	1
Trionychidae:		
Florida soft-shelled turtle.....	<i>Trionyx ferox</i>	6
African soft-shelled turtle.....	<i>Trionyx triunguis</i>	2
Pelomedusidae:		
African water turtle.....	<i>Pelomedusa subrufa</i>	2
African black mud turtle.....	<i>Pelusios subniger</i>	1
Amazon spotted turtle.....	<i>Podocnemis unifilis</i>	7
Chelidae:		
South American side-necked turtle..	<i>Batrachemys nasuta</i>	2
Australian side-necked turtle.....	<i>Chelodina longicollis</i>	3
Kreff's turtle.....	<i>Emydura krefftii</i>	3
Murray turtle.....	<i>Emydura macquarrii</i>	6
Small side-necked turtle.....	<i>Hydromedusa tectifera</i>	2
South American gibba turtle.....	<i>Mesoclemmys gibba</i>	2
Large side-necked turtle.....	<i>Phrynops hilarii</i>	12
Flat-headed turtle.....	<i>Platemys platycephala</i>	9

AMPHIBIANS

CAUDATA

Amphiumidae:		
Congo eel.....	<i>Amphiuma means</i>	4
Ambystomidae:		
Tiger salamander.....	<i>Ambystoma tigrinum</i>	2
Small-mouthed salamander.....	<i>Ambystoma texanum</i>	1
Salamandridae:		
Red-bellied newt.....	<i>Cynops pyrrhogaster</i>	12
Red-spotted newt.....	<i>Diemictylus viridescens</i>	15

SALIENTIA

Bufoinae:		
American toad.....	<i>Bufo americanus</i>	6
Forest toad.....	<i>Bufo blombergii</i>	1
Giant toad.....	<i>Bufo marinus</i>	5
Cuban toad.....	<i>Bufo pellocephalus</i>	6
Pelobatidae:		
Spadefoot toad.....	<i>Scaphiopus holbrookii</i>	7
Pipidae:		
Surinam toad.....	<i>Pipa pipa</i>	20
Leptodactylidae:		
Colombian horned frog.....	<i>Ceratophrys calcarata</i>	2
Argentine horned frog.....	<i>Ceratophrys ornata</i>	1
Hylidae:		
Squirrel tree frog.....	<i>Hyla squirella</i>	6
Green tree frog.....	<i>Hyla cinerea</i>	1
Gray tree frog.....	<i>Hyla versicolor</i>	13
Microhylidae:		
Narrow-mouthed toad.....	<i>Microhyla olivacea</i>	2

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Ranidae:		
African bull frog.....	<i>Rana adspersa</i>	7
American bull frog.....	<i>Rana catesbeiana</i>	1
Green frog.....	<i>Rana clamitans</i>	20
Leopard frog.....	<i>Rana pipiens</i>	Many
Rhacophoridae:		
African flash tree frog.....	<i>Hylambates maculatus</i>	2
Dendrobatidae:		
Green poison-arrow frog.....	<i>Dendrobates tinctorius</i>	1

ARTHROPODS

DECAPODA

Cenobitidae:		
Land hermit crab.....	<i>Coenobita clypeatus</i>	Many

ARANEIDA

Theraphosidae:		
Tarantula.....	<i>Eurypelma hentzi</i>	1
Theridiidae:		
Black-widow spider.....	<i>Latrodectus mactans</i>	1

SCORPIONIDA

Vejovidae:		
Stripe-tailed scorpion.....	<i>Vejovis spinigerus</i>	1
African giant black scorpion.....	<i>Pandinus imperator</i>	2

ORTHOPTERA

Blattidae:		
Tropical giant cockroach.....	<i>Blaberus giganteus</i>	Many

MOLLUSKS

PULMONATA

Planorbidae:		
Pond snails.....	<i>Helisoma trivolvis</i>	20

FISHES

NEOCERATODONTOIDEI

Lepidosirenidae:		
South American lungfish.....	<i>Lepidosiren paradoxa</i>	1
Protopteridae:		
African lungfish.....	<i>Protopterus annectens</i>	1

OSTARIOPHYSOIDEI

Characidae:		
Metynnis.....	<i>Metynnis roosevelti</i>	2
Gymnotidae:		
African knifefish.....	<i>Sternarchella schotti</i>	2
Cyprinidae:		
Zebrafish.....	<i>Brachydanio rerio</i>	17
White Cloud Mountain fish.....	<i>Tanichthys albonubes</i>	4

<i>Family and common name</i>	<i>Scientific name</i>	<i>Number</i>
Cobitidae:		
Large kuhlii.....	<i>Acanthopthalmus semicinctus</i>	1
Callichthyidae:		
Corydoras.....	<i>Corydoras hastatus</i>	2
Corydoras scavenger catfish.....	<i>Corydoras paleatus</i>	1
Loricariidae:		
Armored catfish.....	<i>Plecostomus plecostomus</i>	2

CYPRINODONTOIDEI

Poeciliidae:		
Blue gambusia.....	<i>Gambusia punctatus</i>	2
Flag-tailed guppy.....	<i>Lebistes reticulatus</i>	10
Guppy.....	<i>Lebistes reticulatus</i>	22
Black mollie.....	<i>Mollienisia latipinna</i>	3
Platy, or moonfish.....	<i>Xiphophorus maculatus</i>	5

PERCOMORPHOIDEI

Anabantoidae:		
Climbing perch.....	<i>Anabas testudineus</i>	3
Blue gourami.....	<i>Trichogaster trichopterus</i>	1
Cichlidae:		
Peacock eichlid.....	<i>Astronotus ocellatus</i>	1
Egyptian mouthbreeder.....	<i>Haplochromis multicolor</i>	1
Angelfish.....	<i>Pterophyllum scalare</i>	5

PYGMY HIPPOPOTAMUSES

Because the National Zoological Park had considerable success in raising pygmy hippopotamuses, it seems advisable to list the breeding record here. The first pygmy hippopotamus to come to the Zoo was a gift from Harvey Firestone, Sr., to President Calvin Coolidge in 1927. It was known as Billy. In 1929 a mate, Hannah, was purchased. In 1940 the Smithsonian Institution-Firestone Expedition returned from Liberia with one young male, which died May 3, 1943, and one adult female (known as Matilda).

Billy and Hannah

August 26, 1931, male, died August 27, 1931, killed by mother.

August 21, 1932, male, died August 22, 1932, killed by mother.

April 29, 1933, male, died April 29, 1933, killed by mother.

May 8, 1938, female, sent to Cole Bros. Circus April 26, 1939.

June 24, 1939, female, prematurely born, died June 25, 1939.

February 25, 1940, female, died October 28, 1942.

May 9, 1941, female, sent to Philadelphia Zoological Gardens March 16, 1944.

February 1, 1943, female, died February 2, 1943.

February 20, 1945, male, sent to Miller Bros. Circus January 7, 1950.

December 21, 1945, female, died December 21, 1945.

October 11, 1947, female, died February 11, 1948.

March 12, 1950, female, sent to Catskill Game Farm June 16, 1953.

June 13, 1951, male, sent to Catskill Game Farm June 16, 1953.

April 26, 1953, female, died November 8, 1953.

June 8, 1954, female, died June 23, 1955.

Billy and Matilda

December 13, 1943, male, sent to Fort Worth (Tex.) Zoo.

March 5, 1947, female (living in NZP).

July 3, 1948, female (living in NZP).

December 20, 1949, female, sent to Sydney, Australia, October 18, 1954.

April 24, 1952, male, died October 8, 1952.

October 2, 1953, female, died September 16, 1954.

January 30, 1955, female, sent to John Seago, England, September 7, 1956.

March 20, 1956, female, sent to L. Ruhe, New York, May 7, 1957.

Matilda and two of her daughters are still living in the National Zoological Park. Billy died on October 11, 1955, and Hannah on March 6, 1958.

FINANCES

Funds for the operation of the National Zoological Park are appropriated annually under the District of Columbia Appropriation Act. The operation and maintenance appropriation for the fiscal year 1959 totaled \$953,800, which includes a supplemental appropriation of \$55,800. This was an increase of \$120,800 over fiscal year 1958. The increase consisted of \$55,800 supplemental for pay increases in accordance with Public Law 85-462 and Wage Board increases approved by the District of Columbia Commissioners in June 1958; \$52,833 to establish 14 new positions; \$4,700 for the purchase of new equipment; \$7,467 increase in miscellaneous supplies. Of the \$953,800 appropriated, \$734,666 was for salaries and \$219,134 for the maintenance and operation of the Zoo. Included in the latter figure were major operational expenditures amounting to \$180,434, consisting of \$65,000 for animal food; \$17,168 for fuel for heating; \$29,545 for materials, building, construction, and repairs; \$44,979 for civil service retirement; \$3,575 for the purchase of animals; \$9,101 for electricity; \$3,633 for telephone, postal, and telegraph services; \$5,000 for veterinarian equipment and supplies; and \$2,433 for Federal employees group life insurance. The balance of \$28,700 in operational funds was expended for other items, including freight, sundry supplies, uniforms, gasoline, road repairs, equipment replacement, and new equipment.

In addition to the regular appropriation, \$50,000 was allotted for capital outlay. This money was used to renovate the deer paddocks at the Connecticut Avenue entrance and to restore the area for aquatic mammals above the sea-lion pool.

PERSONNEL

There are 158 authorized positions at the Zoo divided as follows: Administrative office, 16; animal department, 58; mechanical department, 50; police department, 27; and grounds department, 7.

Lee O. Burris, who was appointed head gardener on March 1, 1954, retired on October 31, 1958. Michael Dubik, formerly assistant head gardener, became the supervisory gardener.

During the year nine police officers completed a police course offered by the University of Maryland, and five keepers attended a course in supervision at the Department of Agriculture Night School.

On March 17, at a luncheon in the Zoo Park Restaurant, six women were honored for their efforts in behalf of the National Zoological Park. Five were wives of Zoo officials or keepers; the sixth was the mother of a keeper, and all had taken baby animals into their homes to care for them, and had successfully raised them for the Zoo. The Director introduced the guests of honor, and Dr. Carmichael, Secretary of the Smithsonian Institution, presented each one with a certificate of appreciation. Those receiving the certificates were Mrs. Lucile Q. Mann, Mrs. Esther S. Walker, Mrs. Elizabeth C. Reed, Mrs. Margaret A. Grimmer, Mrs. Louise E. Gallagher, and Mrs. Nettie L. Stroman.

INFORMATION AND EDUCATION

The Zoo continues to handle a large correspondence with persons all over the world who write for information regarding animals. From every part of this country citizens write to the Zoo as a national institution. Telephone calls come in constantly, asking for identification of animals, proper diets, or treatment of disease. Visitors to the office as well as to the animal exhibits are constantly seeking information.

The Director spoke before six civic groups and one school group and appeared on six television programs, displaying animals from the Zoo.

A symposium on "Recognition and Treatment of Snake Bite" was given to the medical staff of Children's Hospital by the Associate Director.

Dr. James F. Wright, veterinarian, published two articles in *Veterinary Medicine*: "Necrotic Stomatitis in an American Elk" (October 1958) and "Treatment of Captive Wild Animals Using an Automatic Projectile Type Syringe" (January 1959).

Malcom Davis, associate headkeeper, continued to write his weekly nature column for the Herndon-Chantilly (Va.) Times and the Loudoun Times Mirror as a public service. He published a monthly article in *All-Pets Magazine* and the *American Cage-Bird Magazine*, as well as biological notes for *The Auk* and notes for the *Pheasant Breeders Gazette*. He spoke on three television programs and broadcast a nature script once a month from the Herndon, Va., radio station. He also spoke to four civic clubs and two high-school biology classes on Zoo animals. Mr. Davis, who is a charter member of the Inter-

national Wild Waterfowl Association, Inc., was appointed to its board of directors in July 1958.

Keepers Burgess, DePrato, Stroman, Welk, and Widman brought young animals to the television screen repeatedly. Many of these programs were on "Time for Science" from WTTG, which is watched by 43,000 students in the District of Columbia, Maryland, and Virginia schools. A half-hour program devoted to the Zoo was broadcast from WTOP, sponsored by the Friends of the National Zoo, and showed the Director and Keepers Maliniak, Stroman, and Gallagher with a young gibbon, a baby chimpanzee, and two hybrid bear cubs.

Ordinarily the Zoo does not conduct guided tours of the park, but exceptions were made for groups of physically handicapped children who visited the park. Two groups were from the District of Columbia Health School, whose children were brought by the Kiwanis Club, and another from the Silver Spring Intermediate School. A small group of blind children were conducted through the Zoo in July 1958. They came from Four Corners (Md.) School and were sponsored by the Lions Club International.

Fifteen members of the Virginia Society of Ornithology, Northern Branch, met at the birdhouse to study Central American birds. The American Society of Mammalogists, during its 3-day meeting in Washington, spent an afternoon on a guided tour of the Zoo. Ten students of chordate anatomy from Baltimore (Md.) Junior College were taken on a tour of the reptile house by Senior Keeper Mario DePrato.

While the Zoo does not conduct a regular research program as such, effort is made to study the animals and to improve their health, housing, and diet in every way possible.

VETERINARIAN'S REPORT

During the past year further uses of the projectile syringe for treatment and immobilization of the large animals in the collection were investigated.

With the help of Dr. Warren Pistey of the New England Institute for Medical Research, experiments utilizing the drug succinylcholine were carried out on numerous species with a view to developing a safe method of immobilizing animals for treatment and such routine procedures as the intradermic tuberculin test. Successful immobilization was accomplished by this method in the zebu, eland, tiger, lion, fallow deer, Virginia deer, gaur, American elk, yak, American bison, giraffe, peccary, and red deer. All these were immobilized without any form of physical restraint being applied. The full particulars of these and other immobilizations are to be published in two papers concerning the use of succinylcholine. The first paper was presented

with motion pictures by Dr. Pistey at the Midwinter Conference of the Midwestern Zoological Park Directors at Columbus, Ohio, in February 1959.

The projectile syringe was used also to effect the capture of an escaped Barbary ape. In this case the drug used for immobilization was the alkaloidal form of nicotine because of its more rapid and predictable action.

The past year has shown that the change in diets instituted in 1958 was a wise move. Wastage sharply decreased, animal reproduction is improved, and a better understanding of the nutritional state of the collection has been gained. One dietary change of major importance was instituted this year by the substitution of a packing-house byproduct for a portion of the raw ground horsemeat formerly used as the carnivore ration. This product has a much better nutritional analysis than horsemeat and requires no labor to bone and grind, as it is supplied ready to use.

As in the past 2 years, all bacterial isolations and identifications were made by Dr. F. R. Lucas, director of the Livestock Sanitary Laboratory at Centreville, Md. At least 300 bacterial isolations and 25 tissue examinations were made by Dr. Lucas for the park in the past year. Most important of the bacterial isolations are the following:

1. Four isolations of *Salmonella typhimurium* from the fecals of hoatzins brought back from British Guiana by Mr. Grimmer.
2. *Salmonella typhimurium* from a great red-crested cockatoo.
3. *Salmonella choleraesuis* var. *kunzendorf* from the spleen of a slow loris.
4. *Salmonella arizonae* from a fox snake.
5. *Salmonella edinburg* from the intestine of a viper.
6. *Salmonella georgia* from the blood of a rainbow snake.
7. *Hemolytic micrococcus* from a young DeBrazza's guenon.
8. *Hemolytic micrococcus* from a pronghorn antelope.
9. Short chain streptococcus and pasteurella from an Indian rhinoceros.

The numerous enteric pathogens being isolated indicate that more attention must be paid to the cleanliness of food preparation and utensil cleaning operations.

In addition to the above, Dr. Lucas also identified *Leptospira* organisms in dark-field examinations of kidney tissues from one of the Zoo's aged bush dogs which showed gross kidney pathology. This and earlier reports indicate that leptospirosis is a problem in small mammals, particularly the canines.

Many parasite identifications were made by A. McIntosh and M. B. Chitwood of the U.S. Department of Agriculture. The following parasites, however, are repeatedly identified from the species indicated:

Bears—*Toxascaris transfuga*.

Cats—*Toxascaris leonine*.

Grant's zebras—*Parascaris zebrae*.

Albatrosses—*Tetraphidium* cestodes.

Snakes—*Neorenifer* flukes, *Bothridium* and *Ophiotaenia* cestodes.

The bears, cats, and zebras have been repeatedly treated with piperazine compounds, but the parasites persist. The zebra paddocks are certainly contaminated with infective parasite eggs, but the cats and bears are on concrete, which should help to break the parasite cycle.

Several of the Zoo's more valuable large mammals died during the year. The first loss was the female wisent, which had a fine calf by her side. She died within minutes of being found down. No previous indication of sickness in the animal was noticed, and nothing unusual was noted on the day prior to death. Necropsy was performed by the Armed Forces Institute of Pathology, but the gross post mortem failed to disclose the cause of death. A condition similar to bovine ketosis was suspected. The 13 bacterial cultures taken from important organs of this animal were all negative for pathogenic organisms.

The Indian rhinoceros received in July 1939 sickened on January 8. Symptomatic treatment was begun, using the projectile syringe, but the animal died the next day. Necropsy was performed by the Armed Forces Institute of Pathology. The pathological diagnosis was hemorrhagic enteritis, ascending cholangitis, arterio and arteriolar nephrosclerosis, hemorrhagic lymphadenitis, cholelithiasis, and acute pneumonitis. Of the 12 bacterial cultures taken from important organs in the animal, all were negative except two blood cultures, from which short chain streptococcus and bipolar rods were isolated.

The male okapi became sick on February 1 and was treated with the projectile method for 6 weeks until a sputum sample was obtained. This was examined by Dr. Feldman of the Veterans' Administration and found positive for acid-fast organisms. The animal was euthanized for necropsy by the AFIP. Examination of the carcass disclosed pulmonary granulomas consistent with tuberculosis infection.

The cage next to the okapi was occupied by a female African black rhinoceros which had been failing in physical condition for some months. A sputum sample obtained from the animal was examined by Dr. Feldman and declared heavily laden with acid-fast bacteria. The animal died on April 21. Necropsy revealed lesions similar to but more extensive and of much longer standing than those found in the okapi. Since these animals had some physical contact over the cage partition, transmission of the infection may have occurred by this route.

A family of elands consisting of an adult male and female and a female calf were all found to have similar lesions during the year.

Dr. A. G. Karlson of the Mayo Foundation was able to isolate *Mycobacterium tuberculosis* var. *boris* from the okapi, rhinoceros, and the two adult elands. Results of examination of culture from a young South American tapir and an old female American bison are being

awaited. In addition, three capybaras and two more old bison showed necropsy lesions of tuberculous infection.

A young DeBrazza's guenon, a 6-week-old squirrel monkey, a pig-tailed macaque, and a moor macaque all sickened and died rapidly with signs and necropsy findings consistent with a virus encephalitis. No definite diagnosis could be made because of lack of facilities. The problem of virus infections is one which needs investigation, since it is probable that immunization procedures would be of considerable value.

Other losses during the year were animals that may have established a longevity record, such as the white-faced heron (*Notophoxyx novae-hollandiae*), which was received September 11, 1938, and died August 20, 1958; Anzio Boy, the hero homing pigeon, hatched in San Prisco, Italy, in 1943, and credited with completing 38 wartime missions in Italy during World War II; the Przewalski horse, born in Philadelphia in 1926; and the African civet (*Civettictis civetta*)¹ which was brought from Liberia by the Smithsonian-Firestone Expedition of 1940.

A long-acting ataraxic drug (Trilafon, Schering) has been used with very encouraging results on the following animals, all except the last being given by projectile syringe:

Gaur, young male. This animal was shipped to the Philadelphia Zoological Gardens after receiving two doses of the drug. He was crated, loaded, and trucked without creating any disturbance.

Yak, male. This very aggressive bull was given one dose of the drug which lasted for 4 days, during which it was possible for the men to enter his pen.

American bison, male. This bull became aggressive when it was necessary to treat one of the old cows. He also began to knock the cow about and keep her down. After the drug had been given he became docile and easily managed.

Brown fallow deer, buck. The animal was extremely excitable until given this drug for the removal of a leg cast.

Pampas cat. This excitable individual was given a small dose of the drug to facilitate trapping and moving to new quarters. The move was easily accomplished, and the effect of the drug lasted during the early acclimatization period in the new cage.

Following are the statistics for the mortality rates during the past fiscal year and a table of comparison with the past 6 years:

Mortality, fiscal year 1959			Total mortality, past 6 fiscal years	
	Deaths	Attrition*	1954	
Mammals	95	25	1955	648
Birds	148	24	1956	735
Reptiles	138	42	1957	618
			1958	549
			1959	550
Total	381	91		472

*Attrition is the term used for those losses due mainly to the trauma of shipment and handling after accession at the Zoo, or before an animal can adapt to cage habitation within the collection.

¹Originally identified as *Civettictis civetta*, the animal was later carried on Zoo records as *Herpestes ichneumon*, but proper identification has been established as *Civettictis civetta*.

COOPERATION

At all times special efforts are made to maintain friendly contacts with other Federal and State agencies, private concerns and individuals, and scientific workers for mutual assistance. As a result the Zoo receives much help and advice and many valuable animals, and in turn it furnishes information and, whenever possible, animals it does not need.

Special acknowledgment is due William G. Vale, U.S. Dispatch Agent in New York City, and Stephen E. Lato, Dispatch Agent in San Francisco, who are frequently called upon to clear shipments of animals coming from abroad, often at great personal inconvenience. The animals have been forwarded to Washington without the loss of a single individual.

Russell Arundel, of Warrenton, Va., gave the Zoo a 13-year-old chestnut gelding, and his son, Arthur W. Arundel, has placed his horse, an 8-year-old quarter horse, also a gelding, on indefinite loan in the National Zoological Park. Both are used by the Zoo Park Police in patrolling areas that could not be covered otherwise.

Gen. William Dunkel of Rockville, Md., presented a number of tropical plants, among them some mango trees, which have been set out in the background of the crocodile cage. Lee O. Burris, formerly head gardener and now retired, brought back from Florida a truckload of cabbage palms, magnolias, yellow honeysuckle, and Spanish moss, which have been used in the birdhouse and in the reptile house. Mrs. Vera S. Hunt of Washington, D.C., donated a large rubber plant, which has been placed in the birdhouse.

Dr. Carlton Herman of the Patuxent Wildlife Refuge gave the Zoo a 300-egg capacity incubator, which has been put to good use in the birdhouse. The U.S. Naval Receiving Station sent 650 pounds of nuts that had been declared unfit for human consumption; from the District of Columbia Dog Pound the Zoo received a quantity of horsemeat and 40 cases of Japanese tuna.

As in the past, the Zoo cooperated with the National Capital Parks and lent small animals to Park naturalists and to the Nature Center in Rock Creek Park for demonstration. In return, the Zoo received a number of specimens as gifts.

VISITORS

Attendance at the Zoo this year reached a total of 4,055,673. In general, this figure is based on estimates rather than actual counts.

Estimated number of visitors for fiscal year 1959

July (1958).....	575, 300	January (1959).....	114, 650
August.....	552, 920	February.....	166, 550
September.....	413, 554	March.....	312, 453
October.....	294, 656	April.....	374, 540
November.....	185, 000	May.....	573, 200
December.....	69, 250	June.....	423, 600
		Total.....	4, 055, 673

Number of bus groups

Locality	Number of groups	Number in groups	Locality	Number of groups	Number in groups
Alabama.....	28	2, 112	Missouri.....	1	21
Connecticut.....	10	343	New Hampshire.....	1	36
Delaware.....	16	579	New Jersey.....	29	1, 235
District of Columbia.....	96	4, 165	New York.....	198	9, 259
Florida.....	48	2, 265	North Carolina.....	275	11, 953
Georgia.....	218	9, 311	Ohio.....	56	2, 287
Illinois.....	2	71	Pennsylvania.....	297	12, 201
Indiana.....	15	574	South Carolina.....	60	2, 514
Iowa.....	1	32	Tennessee.....	75	3, 018
Kentucky.....	27	944	Texas.....	1	40
Louisiana.....	3	87	West Virginia.....	59	2, 375
Maine.....	6	243	Wisconsin.....	5	210
Maryland.....	706	33, 788	Virginia.....	779	32, 831
Massachusetts.....	11	411	U.S.A.....	1	77
Michigan.....	9	343	Total.....	3, 050	121, 937
Minnesota.....	9	313			
Mississippi.....	8	252			

Groups from foreign countries

Africa.....	1	88
China.....	1	12
Norway.....	2	73
Foreign exchange students.....	1	1, 100
Total.....	5	1, 273

About 2 p.m. each day the cars then parked in the Zoo are counted and listed according to the State, Territory, or country from which they come. This is, of course, not a census of the cars coming to the Zoo but is valuable in showing the percentage of attendance by States

of people in private automobiles. Many District of Columbia, Maryland, and Virginia cars come to the Zoo to bring guests from other States. The tabulation for the fiscal year 1959 is as follows:

<i>Percentage</i>		<i>Percentage</i>	
Maryland -----	31.1	California -----	0.7
Virginia -----	22.1	Connecticut -----	.7
District of Columbia -----	21.7	South Carolina -----	.7
Pennsylvania -----	4.0	Illinois -----	.6
New York -----	3.0	Michigan -----	.6
North Carolina -----	2.1	Tennessee -----	.6
New Jersey -----	1.6	Texas -----	.5
Ohio -----	1.6	Alabama -----	.4
West Virginia -----	1.2		
Florida -----	1.0	Total -----	95.0
Massachusetts -----	0.8		

The remaining 5 percent came from other States, Africa, Belgium, Canada, Canal Zone, France, Germany, Guam, Japan, Manitoba, Mexico, New Brunswick, Newfoundland, Nicaragua, Nova Scotia, Okinawa, Puerto Rico, and El Salvador.

On the days of even small attendance there are cars parked in the Zoo from at least 15 States, Territories, the District of Columbia, and foreign countries. On average days there are cars from about 22 States, Territories, the District of Columbia, and foreign countries; and during the periods of greatest attendance the cars represent not less than 34 different States, Territories, and countries.

Parking spaces in the Zoo now accommodate 1,079 cars when the bus parking place is utilized and 969 cars when it is not used.

BUILDINGS, GROUNDS, AND ENCLOSURES

Most of the year's work done throughout the Zoo was with a view to improving visitor and employee safety, continuing the effort started in the last quarter of the previous year. The new type of visitor safety fence, 46 inches high with a 12-inch 45° angle outward at the top, has been installed around the bear pits, the elephant pools, and the lion house. Additional horizontal bars were placed on the outside lion cages.

The ceiling of the birdhouse was patched and replastered where necessary. In addition to the large areas of deterioration which were readily discernible, Hurricane Hazel, in 1954, did much damage not apparent until extensive plaster repairs were underway. It had been necessary to keep one wing closed for a year. The inside of the birdhouse was repainted, using light sunny colors. The cages in the "new" wing of the birdhouse have been completely redecorated, furnishing a more naturalistic setting with extensive use of plantings and trees. Not only are the birds exhibited in a much more inter-

esting fashion but they seem happier and more contented. The keepers have done all this work on their own initiative.

Some of the cages of the reptile house were redecorated with additional stonework, giving the reptiles crevices to lie in and providing them a sense of security and at the same time keeping them on exhibition. Some of the cages were repainted in pastel colors, and several were equipped with fluorescent lights, as a pilot exhibit anticipating the day when all of them will be lighted in this manner. The glass at the top of all the permanent reptile cages was replaced by wire screening to provide better ventilation; four of the portable cages were reconstructed out of aluminum as pilot exhibits.

The parking-lot fill near the elephant house was completed, as well as the fill between the hay barn and the incinerator, and a service road was built from the sheep mountain to the basement of the reptile house, thus furnishing vehicular access from the reptile house to the buffalo pens. This means that various park automobiles can service this entire area without interfering with public traffic.

The year's appropriation included \$50,000 in capital outlay for the replacement and refurbishing of the hoofed-stock pens at the Connecticut Avenue entrance and the aquatic-mammal area above the sea-lion pool. The two pens on the right side of the walk leading to the birdhouse were refenced, using chain-link fence, and slightly enlarged; terraced walls were put in, resurfaced with dirt, and seeded. This hillside had been unsightly because of years of erosion. The two pens in the triangle between the walk leading to the birdhouse and the Connecticut Avenue-Harvard Street road were refenced, using chain-link fencing, and enlarged, the surface was raised by the use of fill dirt, and another pen was added. The new type of visitors' fence was put around these new pens. A new pen for deer was installed behind the beaver area and the sea-lion pool. The deer can be seen across the valley from the walk in front of the bear dens.

Work on the aquatic-mammal area should be completed in the early part of fiscal year 1960. It is hoped that in the coming year the otter exhibit will also be functioning once again. In years past the public took a keen interest in watching otters at play, but this section of "Beaver Valley" was abandoned because of lack of funds to maintain it.

The work of the gardener's force was mainly that of removing dead trees, which are a menace to both animals and visitors, and replacing them with young trees. In all, 243 trees were cut down in the course of the year. The grounds department also furnishes the animal department with forage for the animals. Heavy logs for the big cats to climb, perches and sawed hollow logs for small mammals, gnawing logs for rodents, and perches for birds are supplied on demand; and

tropical plants for indoor cages and the buildings are supplied and cared for.

Activities in the Police Department continue to show a marked increase, in keeping with the larger visitor attendance. The police force was expanded by the addition of four men, and two horses were added, thereby permitting additional patrols in and around heavily wooded areas of the park. A safety committee was set up, with regularly scheduled meetings of all park personnel, designed to insure all possible safety precautions for the protection of visitors and employees. Additional emphasis with regard to traffic-law enforcement resulted in an increase in the number of arrests for traffic violations. The total number of visitors stopping in the police station for information of various sorts was 13,740, an increase of 6,914 over the preceding year. First-aid cases also increased; a total of 809 persons were treated, principally for minor injuries.

PLANS FOR THE FUTURE

A new office to replace the 154-year-old "mansion" is imperative. The present administration building, while a historic landmark, is not suited to the purpose for which it is being used, nor is it safe, being honeycombed with termites and rotted from dampness. A modern building, with properly arranged offices, library stacks and shelves, a conference room, and a small laboratory, is badly needed.

All the facilities at the National Zoological Park are based on antiquated installations and should be modernized, starting with such basic necessities as water, electricity, sewage, and heating. It is hoped that a master plan can be drawn for the Zoo so that all future construction and work may be coordinated.

Respectfully submitted.

THEODORE H. REED, *Director.*

Dr. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the Canal Zone Biological Area

SIR: It gives me pleasure to present herewith the annual report on the Canal Zone Biological Area for the fiscal year ended June 30, 1959.

SCIENTISTS, STUDENTS, AND OBSERVERS

Following is the list of 54 scientists, students, and observers who visited the island last year and stayed for several days, in order to conduct scientific research or observe the wildlife of the area. In addition, approximately 40 others spent 1 day and 1 night on the island.

<i>Name</i>	<i>Principal interest</i>
Anderson, Eugene, Santa Monica, Calif.	Bird observation.
Barth, Robert H., Harvard University.	Study of interspecific relations of formicariids in mixed species flocks.
Bennett, Charles, University of California, Los Angeles.	Temperature and humidity gradients in forest.
Blest, Dr. A. D., University College, London.	Behavior of sphingid and saturniid moths.
Bruno, Kent, Ohio State University.	Assistant to Dr. Hartman.
Burkhart, Mrs. Harriet, Sarasota, Fla.	Nature writing.
Carpenter, Dr. C. R., Pennsylvania State University.	Primate population and social organization of B.C.I.
Carpenter, Lane, Perkiomen School.	Assistant to Dr. Carpenter.
Clark, Dr. Walter, Eastman Kodak Co.	Inspection of facilities.
Cox, Mr. and Mrs. George W., University of Illinois.	Photographic test.
Darnton, Mr. and Mrs. Rupert, Kent, England.	Physiology of tropical birds.
Dolan, John, Pittsburgh, Pa.	Bird studies.
Drayton, Charles, New York.	Photographing and collecting reptiles, amphibians, and insects.
Dulaney, James A., Smithsonian Institution.	Observation of wildlife.
Dybas, Henry, Chicago Natural History Museum.	Specialist on ptiliid beetles.
Elms, Alan, Pennsylvania State University.	Assistant to Dr. Carpenter.
Emerson, Guy, Kress Foundation, New York.	Observation of wildlife.

<i>Name</i>	<i>Principal interest</i>
Enders, Dr. Robert, Swarthmore College.	Survey of mammal population.
Engesland, Rolf, Oslo, Norway.	Assistant to Per Host.
Fast, A. H., Arlington, Va.	Bird observation.
Greene, Earle R., Los Angeles, Calif.	Bird observation.
Grégoire, Dr. and Mrs. Charles, Brussels, Belgium.	Microscopy of insect blood.
Halka, Dr. Olli, Columbia University, New York.	Cytochemical study of the Homoptera
Harbison, Charles F., Natural History Museum, San Diego, Calif.	Collection of arthropods.
Hartman, Dr. Frank, Ohio State University.	Muscle study of birds and adrenal gland.
Host, Per, Oslo, Norway.	Photography and sound recording.
Kaufmann, Jack, University of California, Berkeley.	Behavior and ecology of coatis.
Kessler, Dietrich, University of Wisconsin.	Wildlife observation.
Kuehn, Robert E., University of California, Berkeley.	Assistant to Dr. Carpenter.
Ledecky-Janecek, Emanuel, New York.	Herpetology.
Mason, Dr. W. A., Pennsylvania State University.	Primate population and social organi- zation of Barro Colorado Island.
McFarland, Douglas, Apple Valley, Calif.	Observation of wildlife.
Motzfeldt, Ulrik, Oslo, Norway.	Assistant to Per Host.
Peterman, Dan, Pennsylvania State University.	Assistant to Dr. Carpenter.
Peterson, David M., California.	Assistant to C. F. Harbison.
Ruud, Miss Berit, Oslo, Norway.	Assistant to Per Host.
Salem, Alan, Chicago Natural History Museum.	Nonmarine mollusks.
Scott, Mr. and Mrs. Peter, Gloucestershire, England.	B. B. C. television.
Smith, John, Harvard University.	Behavior of flycatchers.
Soper, Dr. Cleveland C., Eastman Kodak Tropical Research Laboratory.	Deterioration studies.
Southwick, Dr. C. H., Ohio University.	Primate population and social organi- zation of Barro Colorado Island.
Vogt, George, U.S. National Museum.	Study of leaf-mining beetles.

<i>Name</i>	<i>Principal interest</i>
Walch, Miss Carolyn R., Johns Hopkins University.	Wildlife observation.
Ward, Mr. and Mrs. R., Kennett Square, Pa.	Bird photography.
Weil, Mr. and Mrs. John, University of California, Berkeley.	Wildlife observation.
Wetmore, Dr. and Mrs. Alexander, Washington, D.C.	Bird observation.
Wyse, Gordon B., Swarthmore College.	Wildlife observation.

VISITORS

Approximately 400 visitors were permitted to visit the island for the day.

Because of the increased number of scientists conducting research on the island, the decision was made to eliminate the Tuesday guided tours through the jungle. Large groups are welcome on Saturdays, however, and visitors interested in natural history are permitted to visit the island whenever transportation is available.

RAINFALL

During the dry season (January through April) of the calendar year 1958, rains of 0.01 inch or more fell during 57 days (216 hours) and amounted to 19.31 inches, as compared to 1.20 inches during 1957. During the wet season of 1958 (May through December), rains of 0.01 inch or more fell on 191 days (669 hours) and amounted to 80.89 inches, as compared to 96.77 inches during 1957. Total rainfall for the year was 100.20 inches. During 34 years of record, the wettest year was 1935 with 143.42 inches, and the driest year was 1930, with only 76.57 inches. March was the driest month of 1958 (2.98 inches) and October the wettest (15.42 inches). The maximum records for short periods were: 5 minutes: 1.30 inches; 10 minutes: 1.65 inches; 1 hour: 4.11 inches; 2 hours: 4.81 inches; 24 hours: 10.48 inches.

BUILDINGS, EQUIPMENT, AND IMPROVEMENTS

Special attention has again been paid to the improvement of existing facilities.

The expansion of the library has continued. A great many new books and journals were received, and most of the older books and journals were re-bound. A temporary librarian completed the cataloging of the collection. The library is now much more useful as an aid to research than it has ever been before.

Many new aviaries, mammal pens, and smaller cages were built this year. Facilities are now available for the keeping of considerable numbers of animals and birds in excellent condition for experimental observations.

TABLE 1.—*Annual rainfall, Barro Colorado Island, C.Z.*

Year	Total inches	Station average	Year	Total inches	Station Average
1925	104. 37		1942	111. 10	108. 55
1926	118. 22	113. 56	1943	120. 29	109. 20
1927	116. 36	114. 68	1944	111. 96	109. 30
1928	101. 52	111. 35	1945	120. 42	109. 84
1929	87. 84	106. 56	1946	87. 38	108. 81
1930	76. 57	101. 51	1947	77. 92	107. 49
1931	123. 30	104. 69	1948	83. 16	106. 43
1932	113. 52	105. 76	1949	114. 86	106. 76
1933	101. 73	105. 32	1950	114. 51	107. 07
1934	122. 42	107. 04	1951	112. 72	107. 28
1935	143. 42	110. 35	1952	97. 68	106. 94
1936	93. 88	108. 98	1953	104. 97	106. 87
1937	124. 13	110. 12	1954	105. 68	106. 82
1938	117. 09	110. 62	1955	114. 42	107. 09
1939	115. 47	110. 94	1956	114. 05	107. 30
1940	86. 51	109. 43	1957	97. 97	106. 98
1941	91. 82	108. 41	1958	100. 20	106. 70

TABLE 2.—*Comparison of 1957 and 1958 rainfall, Barro Colorado Island (inches)*

Month	Total		Station average	Years of record	1958 excess or deficiency	Accumulated excess or deficiency
	1957	1958				
January	0. 56	4. 26	2. 21	33	+2. 05	+2. 05
February	. 57	7. 34	1. 41	33	+5. 93	+7. 98
March	. 02	2. 98	1. 21	33	+1. 77	+9. 75
April	. 05	4. 73	3. 02	34	+1. 71	+11. 46
May	6. 37	12. 22	10. 91	34	+1. 31	+12. 77
June	5. 97	8. 89	10. 89	34	-2. 00	+10. 77
July	10. 86	9. 54	11. 60	34	-2. 06	+8. 71
August	21. 90	12. 35	12. 47	34	-. 12	+8. 59
September	12. 40	10. 64	10. 06	34	+. 58	+9. 17
October	17. 22	15. 42	14. 04	34	+1. 38	+10. 55
November	17. 96	7. 16	18. 44	34	-11. 28	-. 73
December	4. 09	4. 67	10. 44	34	-5. 77	-6. 50
Year	97. 97	100. 20	106. 70			-6. 50
Dry season	1. 20	19. 31	7. 85			+11. 46
Wet season	96. 77	80. 89	98. 85			-17. 96

A 60- by 30-foot wire-screen shed was built to provide space for the smaller cages and storage of materials. This has relieved much of the crowding problem at the station.

In connection with the research on tropical birds now being conducted by George W. Cox of the University of Illinois, two large constant-temperature chambers were built and installed in the new storage shed. These chambers were financed by a grant from the National Science Foundation to Dr. S. Charles Kendeigh of the University of Illinois.

Various minor items of research and collecting equipment, including traps and trapping nets, and a Sniperscope for work at night, were also procured this year.

A new system of electric cables from the generators to the laboratories and living quarters on the island was installed, to permit the simultaneous use of two generators. This has doubled the effective electric power supply of the station.

A new winch, 25-h.p., 3,300-pound capacity, was purchased and installed to replace the old one.

Extensive repairs, almost a complete rebuilding job, are being made to the termite-infested Chapman House. This should provide adequate living quarters for three or four scientists.

Routine maintenance activities included repainting the inside and outside of most of the other station buildings, minor repairs to the docks, and new roofing for some of the buildings.

A new 15-foot Fiberglas boat was bought to replace the old aluminum speedboat, and extensive repairs were made to the launch *Snook*. The old boat channel from the canal to the station dock on the island was widened and deepened. Means of transportation with the mainland are now in excellent condition.

A jeep was purchased to replace the $\frac{1}{2}$ -ton truck and has proved to be extremely useful for work in the more remote parts of the Canal Zone and the Republic of Panama.

It was necessary to move the office in Diablo Heights, as the building in which it was located is being torn down. The office is now in temporary quarters in the Ancon Court House.

OTHER ACTIVITIES

In order to increase the available opportunities for research at the Canal Zone Biological Area, a small piece of land (one-sixteenth of a square mile) was procured on the mainland. This new area consists of grassland and forest edge and is located inside the Navy Pipeline Reservation between Gamboa and Montelirio on the east side of the canal. The Navy also granted permission to accredited scientists to work along the 14-mile road running through the Pipeline Reservation. This road runs through areas of mixed grassland and second-growth scrub and forest of different ages and types. Thus, scientists working at the Canal Zone Biological Area will be able to conduct research in a variety of environments quite different from the

heavy mature forest on Barro Colorado itself. Research in this mainland area will be completely undisturbed, as the whole Pipeline Reservation is closed to the general public.

The policy of helping promising graduate students in biology has continued. Charles F. Bennett, Jr., of the University of California in Los Angeles, completed the main part of his study of temperature and humidity gradients in the forest on Barro Colorado; but additional climatological data are still being collected and will be included in Mr. Bennett's published report. Robert H. Barth, of Harvard University, completed a preliminary analysis of the behavior of birds of the family Formicariidae in mixed flocks in the forest.

The analysis of the behavior of sphingid and saturniid moths continued by Dr. A. D. Blest of University College, London, which was supported by a grant from the National Science Foundation to the resident naturalist, was completed. Dr. Blest's results will be published shortly. A second research project supported by a grant from the National Science Foundation to the resident naturalist, a comparative study of the evolution and behavior of certain tropical birds, is still in progress. A new research project on the evolution and behavior of American monkeys was started this year.

Plans have already been made to move the office on the mainland into larger quarters in the former Ancon Post Office Building, as soon as these became available after remodeling.

FINANCES

Trust funds for maintenance of the island and its living facilities are obtained by collections from visitors and scientists, table subscriptions, and donations.

The following institutions continued their support to the laboratory through the payment of table subscriptions: Eastman Kodak Co., New York Zoological Society, and Smithsonian Institution. Donations are also gratefully acknowledged from the following: Eugene Eisenmann, C. M. Goethe, and Frank Hartman.

PLANS AND REQUIREMENTS

The improvement of the library will continue. It will be necessary to obtain new books and journals as they are published and to complete present journal files.

It is hoped to continue the program of employing temporary biological aides. Arrangements have been made to employ John H. Kaufmann, of the University of California, to continue his research on the behavior and ecology of the coati and other carnivores on Barro Colorado Island and to begin a census of the vertebrate species in the mainland area.

It is still planned to remodel the second floor of the Old Laboratory Building to make available separate rooms and to provide additional washing and toilet facilities. Now that additional electric power is available, airconditioning in some of the other living quarters and in the laboratory space on the second floor of the New Laboratory Building is anticipated.

ACKNOWLEDGMENTS

The Canal Zone Biological Area can operate only with the excellent cooperation of the Canal Zone Government and the Panama Canal Company. Thanks are due especially to the Lt. Gov. John D. McElheny, the Executive Secretary Paul Runnestrand and his staff; Lieutenant Colonel Brown; the Customs and Immigration officials; and the Police Division. Also deeply appreciated are the technical advice and assistance provided by P. Alton White, Chief of the Dredging Division, and members of his staff; C. C. Soper of the Eastman Kodak Co.; and Lt. K. E. McCall and other members of the Signal Corps Meteorological Team No. 2.

Respectfully submitted.

MARTIN H. MOYNIHAN,
Resident Naturalist.

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the International Exchange Service

SIR: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1959:

The Smithsonian Institution is the official United States agency for the exchange with other nations of governmental, scientific, and literary publications. The International Exchange Service, initiated by the Smithsonian Institution in the early years of its existence for the interchange of scientific publications between learned societies and individuals in the United States and those of foreign countries, serves as a means of developing and executing in part the broad and comprehensive objective, "the diffusion of knowledge." It was later designated by the U.S. Government as the agency for the transmission of official documents to selected depositories throughout the world, and it continues to execute the exchanges pursuant to conventions, treaties, and other international agreements.

The number of packages of publications received for transmission during the year was 1,129,476, an increase of 34,678 packages over the previous fiscal year. The weight of the packages received was 767,389 pounds, an increase of 24,060 pounds.

The average weight of the individual package was 10.87 ounces as compared to the 10.86-ounce average for the fiscal year of 1958.

The publications received from foreign sources for addressees in the United States and from domestic sources for shipment abroad are classified as shown in the following table:

Classification	Packages		Weight	
	Number	Number	Pounds	Pounds
U.S. parliamentary documents sent abroad.....	626, 465		226, 119	
Publications received in return for parliamentary documents.....		5, 775		10, 325
U.S. departmental documents sent abroad.....	239, 401		218, 261	
Publications received in return for departmental documents.....		5, 146		13, 059
Miscellaneous scientific and literary publications sent abroad.....	189, 721		199, 414	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States.....		62, 968		100, 211
Total.....	1, 055, 587	73, 889	643, 794	123, 595
Grand total.....	1, 129, 476		767, 389	

The packages of publications are forwarded to the exchange bureaus of foreign countries by freight or, where shipment by such means is impractical, to the foreign addressees by direct mail. Distribution in the United States of the publications received through the foreign exchange bureaus is accomplished primarily by mail, but by other means when more economical. The number of boxes shipped to the foreign exchange bureaus was 2,840, or 242 less than for the previous year. Of these boxes, 899 were for depositories of full sets of U.S. Government documents, these publications being furnished in exchange for the official publications of foreign governments which are received for deposit in the Library of Congress. The weight of packages forwarded by mail and by means other than freight was 271,372 pounds.

There was allocated to the International Exchange Service for transportation \$30,294.47. With this amount it was possible to effect the shipment of 784,571 pounds, which was 34,316 pounds less than was shipped in the previous year. However, approximately 7,374 pounds of the full sets of U.S. Government documents accumulated during the year because the Library of Congress had requested suspension of shipment to certain foreign depositories.

During the year, ocean freight rates per cubic foot continued at the 1958 level. The transportation cost for hauling books and periodicals to the Baltimore piers also remained at the 1958 level.

With the exception of those to Taiwan, no shipments are being made to China, North Korea, and Communist-controlled area of Vietnam.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

The number of sets of U.S. official publications received by the Exchange Service for transmission abroad in return for the official publications sent by foreign governments for deposit in the Library of Congress is now 106 (63 full and 43 partial sets), listed below. Changes that occurred during the year are shown in the footnotes.

DEPOSITORIES OF FULL SETS

ARGENTINA: División Biblioteca, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.

AUSTRALIA: Commonwealth National Library, Canberra.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

QUEENSLAND: Parliamentary Library, Brisbane.

SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.

TASMANIA: Parliamentary Library, Hobart.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: State Library, Perth.

AUSTRIA: Administrative Library, Federal Chancellery, Vienna.

BELGIUM: Bibliothèque Royale, Bruxelles.

BRAZIL: Biblioteca Nacional, Rio de Janeiro.

- BULGARIA:** Bulgarian Bibliographical Institute, Sofia.¹
- BURMA:** Government Book Depot, Rangoon.
- CANADA:** Library of Parliament, Ottawa.
- MANITOBA:** Provincial Library, Winnipeg.
- ONTARIO:** Legislative Library, Toronto.
- QUEBEC:** Library of the Legislature of the Province of Quebec.
- CEYLON:** Department of Information, Government of Ceylon, Colombo.
- CHILE:** Biblioteca Nacional, Santiago.
- CHINA:** National Central Library, Taipei, Taiwan.
- National Chengchi University, Taipei, Taiwan.
- COLOMBIA:** Biblioteca Nacional, Bogotá.
- COSTA RICA:** Biblioteca Nacional, San José.
- CUBA:** Ministerio de Estado, Canje Internacional, Habana.
- CZECHOSLOVAKIA:** University Library, Prague.
- DENMARK:** Institut Danois des Échanges Internationaux, Copenhagen.
- EGYPT:** Bureau des Publications, Ministère des Finances, Cairo.
- FINLAND:** Parliamentary Library, Helsinki.
- FRANCE:** Bibliothèque Nationale, Paris.
- GERMANY:** Deutsche Staatsbibliothek, Berlin.
- Free University of Berlin, Berlin-Dahlem.
- Parliamentary Library, Bonn.
- GREAT BRITAIN:**
- ENGLAND:** British Museum, London.
- LONDON:** London School of Economics and Political Science. (Depository of the London County Council.)
- HUNGARY:** Library of Parliament, Budapest.¹
- INDIA:** National Library, Calcutta.
- Central Secretariat Library, New Delhi.
- Parliament Library, New Delhi.
- INDONESIA:** Ministry for Foreign Affairs, Djakarta.
- IRELAND:** National Library of Ireland, Dublin.
- ISRAEL:** State Archives and Library, Hakirya, Jerusalem.
- ITALY:** Ministero della Pubblica Istruzione, Rome.
- JAPAN:** National Diet Library, Tokyo.²
- MEXICO:** Secretaría de Relaciones Exteriores, Departamento de Información para el Extranjero México, D.F.
- NETHERLANDS:** Royal Library, The Hague.
- NEW ZEALAND:** General Assembly Library, Wellington.
- NORWAY:** Utenriksdepartementets Bibliothek, Oslo.
- PERU:** Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.
- PHILIPPINES:** Bureau of Public Libraries, Department of Education, Manila.
- POLAND:** Bibliothèque Nationale, Warsaw.¹
- PORTUGAL:** Biblioteca Nacional, Lisbon.
- SPAIN:** Biblioteca Nacional, Madrid.
- SWEDEN:** Kungliga Biblioteket, Stockholm.
- SWITZERLAND:** Bibliothèque Centrale Fédérale, Berne.
- TURKEY:** National Library, Ankara.
- UNION OF SOUTH AFRICA:** State Library, Pretoria, Transvaal.
- UNION OF SOVIET SOCIALIST REPUBLICS:** All-Union Lenin Library, Moscow.

¹ Shipment suspended.

² Receives two sets.

UNITED NATIONS: Library of the United Nations, Geneva, Switzerland.
 URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
 VENEZUELA: Biblioteca Nacional, Caracas.
 YUGOSLAVIA: Bibliografski Institut, Belgrade.²

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Library of the Afghan Academy, Kabul.
 BOLIVIA: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.
 BRAZIL: MINAS GERIAS: Departamento Estadual de Estatística, Belo Horizonte.
 BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara
 CANADA:
 ALBERTA: Provincial Library, Edmonton.
 BRITISH COLUMBIA: Provincial Library, Victoria.
 NEW BRUNSWICK: Legislative Library, Fredericton.
 NEWFOUNDLAND: Department of Provincial Affairs, St. John's.
 NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
 SASKATCHEWAN: Legislative Library, Regina.
 DOMINICAN REPUBLIC: Biblioteca de la Universidad de Santo Domingo, Ciudad Trujillo.
 ECUADOR: Biblioteca Nacional, Quito.
 EL SALVADOR:
 Biblioteca Nacional, San Salvador.
 Ministerio de Relaciones Exteriores, San Salvador.
 GREECE: National Library, Athens.
 GUATEMALA: Biblioteca Nacional, Guatemala.
 HAITI: Bibliothèque Nationale, Port-au-Prince.
 HONDURAS:
 Biblioteca Nacional, Tegucigalpa.
 Ministerio de Relaciones Exteriores, Tegucigalpa.
 ICELAND: National Library, Reykjavik.
 INDIA:
 BOMBAY: Secretary to the Government, Bombay.
 BIHAR: Revenue Department, Patna.
 UTTAR PRADESH:
 University of Allahabad, Allahabad.
 Secretariat Library, Lucknow.
 WEST BENGAL: Library, West Bengal Legislative Secretariat, Assembly House, Calcutta.
 IRAN: Imperial Ministry of Education, Tehran.
 IRAQ: Public Library, Baghdad.
 JAMAICA:
 Colonial Secretary, Kingston.
 University College of the West Indies, St. Andrew.
 LEBANON: American University of Beirut, Beirut.
 LIBERIA: Department of State, Monrovia.
 MALAYA: Federal Secretariat, Federation of Malaya, Kuala Lumpur.
 MALTA: Minister for the Treasury, Valletta.
 NICARAGUA: Ministerio de Relaciones Exteriores, Managua.
 PAKISTAN: Central Secretariat Library, Karachi.
 PANAMA: Ministerio de Relaciones Exteriores, Panamá.
 PARAGUAY: Ministerio de Relaciones Exteriores, Sección Biblioteca, Asunción.
 PHILIPPINES: House of Representatives, Manila.

SCOTLAND: National Library of Scotland, Edinburgh.

SIAM: National Library, Bangkok.

SINGAPORE: Chief Secretary, Government Offices, Singapore.

SUDAN: Gordon Memorial College, Khartoum.

VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

There are now being sent abroad 85 copies of the Federal Register and 95 copies of the Congressional Record. This is an increase over the preceding year of five copies of the Federal Register and of four copies of the Congressional Record. The countries to which these journals are being forwarded are given in the following list:

DEPOSITORIES OF CONGRESSIONAL RECORD AND FEDERAL REGISTER

ARGENTINA:

Biblioteca de la H. Legislatura de Mendoza, Mendoza.³

Biblioteca del Poder Judicial, Mendoza.⁴

Boletín Oficial de la República Argentina, Ministerio de Justicia e Instrucción Pública, Buenos Aires.

Cámara de Diputados Oficina de Información Parlamentaria, Buenos Aires.

AUSTRALIA:

Commonwealth National Library, Canberra.

NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.

QUEENSLAND: Chief Secretary's Office, Brisbane.

VICTORIA: Public Library of Victoria, Melbourne.⁴

WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.

BRAZIL: Secretaria de Presidencia, Rio de Janeiro.³

BRITISH HONDURAS: Colonial Secretary, Belize.

CANADA:

Library of Parliament, Ottawa.

Clerk of the Senate, Houses of Parliament, Ottawa.

CEYLON: Ceylon Ministry of Defense and External Affairs, Colombo.³

CHILE: Biblioteca del Congreso Nacional, Santiago.^{3, 5}

CHINA:

Legislative Yuan, Taipei, Taiwan.³

Taiwan Provincial Government, Taipei, Taiwan.

CUBA:

Biblioteca del Capitolio, Habana.

Biblioteca Pública Panamericana, Habana.⁴

CZECHOSLOVAKIA: Ceskoslovenska Akademie Ved, Prague.³

EGYPT: Ministry of Foreign Affairs, Egyptian Government, Cairo.³

FRANCE:

Bibliothèque Assemblée Nationale, Paris.

Bibliothèque Conseil de la République, Paris.

Library, Organization for European Economic Cooperation, Paris.³

Research Department, Council of Europe, Strasbourg.³

Service de la Documentation Étrangère, Assemblée Nationale, Paris.³

³ Congressional Record only.

⁴ Federal Register only.

⁵ Added during the year.

GERMANY :

- Amerika-Institute der Universität München, München.²
- Archiv, Deutscher Bundestag, Bonn.
- Bibliothek der Instituts für Weltwirtschaft an der Universität Kiel, Kiel-Wik.
- Bibliothek Hessischer Landtag, Wiesbaden.³
- Der Bayrische Landtag, Munich.^{3,4}
- Deutsches Institut für Rechtswissenschaft, Potsdam-Babelsberg II.¹
- Deutscher Bundesrat, Bonn.³
- Deutscher Bundestag, Bonn.³
- Hamburgisches Welt-Wirtschafts-Archiv, Hamburg.

GHANA : Chief Secretary's Office, Accra.³

GREAT BRITAIN :

- Department of Printed Books, British Museum, London.
- House of Commons Library, London.³
- N.P.P. Warehouse, H.M. Stationery Office, London.^{1, 7}
- Printed Library of the Foreign Office, London.
- Royal Institute of International Affairs, London.³

GREECE : Bibliothèque, Chambre des Députés Hellénique, Athens.

GUATEMALA : Biblioteca de la Asamblea Legislativa, Guatemala.

HAITI : Bibliothèque Nationale, Port-au-Prince.

HONDURAS : Biblioteca del Congreso Nacional, Tegucigalpa.

HUNGARY : National Library, Budapest.

INDIA :

- Civil Secretariat Library, Lucknow, United Provinces.⁴
- Indian Council of World Affairs, New Delhi.³
- Jammu and Kashmir Constituent Assembly, Srinagar.⁴
- Legislative Assembly, Government of Assam, Shillong.³
- Legislative Assembly Library, Lucknow, United Provinces.
- Kerala Legislature Secretariat, Trivandrum.^{3,8}
- Madras State Legislature, Madras.³
- Parliament Library, New Delhi.
- Servants of Indian Society, Poona.³

IRELAND : Dail Eireann, Dublin.

ISRAEL : Library of the Knesset, Jerusalem.

ITALY :

- Biblioteca Camera dei Deputati, Rome.
- Biblioteca del Senato della Repubblica, Rome.
- Periodicals Unit, Food and Agriculture Organization of the United Nations, Rome.⁴
- International Institute for the Unification of Private Law, Rome.⁴

JAPAN :

- Library of the National Diet, Tokyo.
- Ministry of Finance, Tokyo.

JORDAN : Parliament of the Hashemite Kingdom of Jordan, Amman.³

KOREA : Secretary General, National Assembly, Seoul.

LUXEMBOURG : Assemblée Commune de la C.E.C.A., Luxembourg.

² Three copies.⁷ Two copies.⁸ Changed from Legislative Assembly Library, Trivandrum.

MEXICO:

- Dirección General Information, Secretaría de Gobernación, Mexico, D.F.
 Biblioteca Benjamin Franklin, México, D.F.
 AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.
 BAJA CALIFORNIA: Gobernador del Distrito Norte, Mexicali.
 CAMPECHE: Gobernador del Estado de Campeche, Campeche.
 CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Guitiérrez.
 CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.
 COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.
 COLIMA: Gobernador del Estado de Colima, Colima.
 GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.⁴
 JALISCO: Biblioteca del Estado, Guadalajara.
 MÉXICO: Gaceta del Gobierno, Toluca.
 MICHOACÁN: Secretaría General de Gobierno del Estado de Miochoacán, Morelia.
 MORELOS: Palacio de Gobierno, Cuernavaca.
 NAYARIT: Gobernador de Nayarit, Tepic.
 NUEVO LEÓN: Biblioteca del Estado, Monterrey.
 OAXACA: Periódico Oficial, Palacio de Gobierno, Oaxaca.⁴
 PUEBLA: Secretaría General de Gobierno, Puebla.
 QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.
 SINALOA: Gobernador del Estado de Sinaloa, Culiacán.
 SONORA: Gobernador del Estado de Sonora, Hermosillo.
 TAMAULIPAS: Secretaría General de Gobierno, Victoria.
 VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.
 YUCATÁN: Gobernador del Estado de Yucatán, Mérida.
 NETHERLANDS: Koninklijke Bibliotheek, The Hague.⁴
 NEW ZEALAND: General Assembly Library, Wellington.
 NORWAY: Library of the Norwegian Parliament, Oslo.
 PANAMA: Biblioteca Nacional, Panama City.⁵
 PHILIPPINES: House of Representatives, Manila.
 POLAND: Kancelaria Rady, Panstwa, Biblioteka Sejmowa, Warsaw.
 PORTUGUESE TIMOR: Repartição Central de Administração Civil, Dili.⁴
 RHODESIA AND NYASALAND: Federal Assembly, Salisbury.^{4 6}
 RUMANIA: Biblioteca Centrala de Stat RPR, Bucharest.⁵
 SPAIN: Secretaria General Tecnica, Presidencia del Gobierno, Madrid.^{4 6}
 SWITZERLAND: Bibliothéque, Bureau International du Travail, Geneva.⁴
 International Labor Office, Geneva.^{4 7}
 Library, United Nations, Geneva.
 UNION OF SOUTH AFRICA:
 CAPE OF GOOD HOPE: Library of Parliament, Cape Town.
 TRANSVAAL: State Library, Pretoria.
 UNION OF SOVIET SOCIALIST REPUBLICS: Fundamental'nii Biblioteka Obschestvennykh Nauk, Moscow.
 URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.
 YUGOSLAVIA: Bibilografski Institut FNRJ, Belgrade.^{5 7}

FOREIGN EXCHANGE SERVICES

Exchange publications for addresses in the countries listed below are forwarded by freight to the exchange services of those countries.

Exchange publications for addresses in other countries are forwarded directly by mail.

LIST OF EXCHANGE SERVICES

- AUSTRIA:** Austrian National Library, Vienna.
- BELGIUM:** Service des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.
- CHINA:** National Central Library, Taipei, Taiwan.
- CZECHOSLOVAKIA:** Bureau of International Exchanges, University Library, Prague.
- DENMARK:** Institut Danois des Échanges Internationaux, Bibliothèque Royale, Copenhagen.
- EGYPT:** Government Press, Publications Office, Bulaq, Cairo.
- FINLAND:** Delegation of the Scientific Societies, Helsinki.
- FRANCE:** Service des Échanges Internationaux, Bibliothèque Nationale, Paris.
- GERMANY (Eastern):** Deutsche Staatsbibliothek, Berlin.
- GERMANY (Western):** Deutsche Forschungsgemeinschaft, Bad Godesberg.
- HUNGARY:** National Library, Széchényi, Budapest.
- INDIA:** Government Printing and Stationery, Bombay.
- INDONESIA:** Minister of Education, Djakarta.
- ISRAEL:** Jewish National and University Library, Jerusalem.
- ITALY:** Ufficio degli Scambi Internazionali, Ministero della Pubblica Istruzione, Rome.
- JAPAN:** Division of International Affairs, National Diet Library, Tokyo.
- KOREA:** Korean Library Association, Seoul.*
- NETHERLANDS:** International Exchange Bureau of the Netherlands, Royal Library, The Hague.
- NEW SOUTH WALES:** Public Library of New South Wales, Sydney.
- NEW ZEALAND:** General Assembly Library, Wellington.
- NORWAY:** Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.
- PHILIPPINES:** Bureau of Public Libraries, Department of Education, Manila.
- POLAND:** Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.
- PORTUGAL:** Secção de Trocas Internacionais, Biblioteca Nacional, Lisbon.
- QUEENSLAND:** Bureau of International Exchange of Publications, Chief Secretary's Office, Brisbane.
- RUMANIA:** International Exchange Service, Biblioteca Centrala de Stat, Bucharest.
- SOUTH AUSTRALIA:** South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.
- SPAIN:** Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Madrid.
- SWEDEN:** Kungliga Biblioteket, Stockholm.
- SWITZERLAND:** Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Palais Fédéral, Berne.
- TASMANIA:** Secretary of the Premier, Hobart.
- TURKEY:** National Library, Ankara.
- UNION OF SOUTH AFRICA:** Government Printing and Stationery Office, Cape Town.

* Changed from Korean National Commission for UNESCO, Seoul.

UNION OF SOVIET SOCIALIST REPUBLICS : Bureau of Book Exchange, State Lenin Library, Moscow.

VICTORIA : Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA : State Library, Perth.

YUGOSLAVIA : Bibliografski Institut FNRJ, Belgrade.

Respectfully submitted.

J. A. COLLINS, *Chief.*

DR. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on the National Gallery of Art

SIR: I have the honor to submit, on behalf of the Board of Trustees, the 22d annual report of the National Gallery of Art, for the fiscal year ended June 30, 1959. This report is made pursuant to the provisions of section 5(d) of Public Resolution No. 14, 75th Congress, 1st session, approved March 24, 1937 (50 Stat. 51).

ORGANIZATION

The statutory members of the Board of Trustees of the National Gallery of Art are the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, ex officio. On May 6, 1959, Rush H. Kress was reelected a general trustee of the National Gallery of Art to serve in that capacity for the term expiring July 1, 1969. The four other general trustees continuing in office during the fiscal year ended June 30, 1959, were Chester Dale, Ferdinand Lammot Belin, Duncan Phillips, and Paul Mellon. On May 7, 1959, Chester Dale was reelected by the Board of Trustees to serve as President of the Gallery and Ferdinand Lammot Belin was reelected Vice President.

The executive officers of the Gallery as of June 30, 1959, are as follows:

Huntington Cairns, Secretary-Treasurer.

John Walker, Director.

Ernest R. Feidler, Administrator.

Huntington Cairns, General Counsel.

Perry B. Cott, Chief Curator.

The three standing committees of the Board, as constituted at the annual meeting on May 7, 1959, are as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States,

Earl Warren, Chairman.

Chester Dale, Vice Chairman.

Ferdinand Lammot Belin.

Secretary of the Smithsonian Institution, Leonard Carmichael.

Paul Mellon.

FINANCE COMMITTEE

Secretary of the Treasury, Robert B. Anderson, Chairman.

Chester Dale, Vice Chairman.

Secretary of the Smithsonian Institution, Leonard Carmichael.

Ferdinand Lammot Belin.

Paul Mellon.

ACQUISITIONS COMMITTEE

Ferdinand Lammot Belin, Chairman.

Duncan Phillips.

Chester Dale.

Paul Mellon.

John Walker.

At the close of the fiscal year full-time Government employees on the staff of the National Gallery of Art numbered 299, as compared with 317 employees at the close of the previous year. The U.S. civil service regulations govern the appointment of employees paid from appropriated public funds.

During the year the Civil Service Commission inspected the personnel management operations of the National Gallery of Art. Suggestions made during that inspection are being incorporated into the personnel management program.

APPROPRIATIONS

For the fiscal year ended June 30, 1959, Congress in the regular annual appropriation for the National Gallery of Art provided \$1,674,000 to be used for salaries and expenses in the operation and upkeep of the Gallery, the protection and care of works of art acquired by the Board of Trustees, and all administrative expenses incident thereto, as authorized by joint resolution of Congress approved March 24, 1937 (20 U.S.C. 71-75; 50 Stat. 51). Congress also included in a supplemental appropriation act \$116,100 to cover pay increases not provided for in the regular appropriation. The total appropriation for the fiscal year was \$1,790,100. The following expenditures and encumbrances were incurred:

Personal services.....	\$1, 452, 022
Other than personal services.....	338, 004
Unobligated balance.....	74
Total.....	1, 790, 100

ATTENDANCE

There were 951,608 visitors to the Gallery during the fiscal year 1959, an increase of 38,127 over the total attendance of 913,481 for the fiscal year 1958. The average daily number of visitors was 2,622.

ACCESSIONS

There were 370 accessions by the National Gallery of Art as gifts, loans, or deposits during the fiscal year.

GIFTS

During the year the following gifts or bequests were accepted by the Board of Trustees:

PAINTINGS

<i>Donor</i>	<i>Artist</i>	<i>Title</i>
Chester Dale.....	Monet.....	Morning Haze.
Syma Busiel.....	Rubens.....	The Meeting of Abraham and Melchizedek.
Lewis Einstein.....	Guardi.....	San Marco.
Avalon Foundation.....	Copley.....	Epes Sargent.
Miss Harriet Winslow.....	George Cuitt, the Younger.	Easby Abbey, near Rich- mond.
Mrs. Edith Stuyvesant Gerry.	Manet.....	The Tragedian (Portrait of Rouviere as Hamlet).
Do.....	Whistler.....	Self-portrait.
Do.....	Whistler.....	George W. Vanderbilt.
Col. and Mrs. Edgar W. Garbisch.	Bauman.....	Geese in Flight.
Do.....	Bauman.....	U.S. Mail Boat.
Do.....	Bradley.....	Little Girl in Lavender.
Do.....	Brown.....	Bareback Riders.
Do.....	Haddoca.....	Red Jacket.
Do.....	Toole.....	Skating Scene.
Do.....	Unknown.....	Burning of Old South Church, Bath, Maine.
Do.....	Unknown.....	Cat and Kittens.
Do.....	Unknown.....	The Cheney Family.
Do.....	Unknown.....	Family Burying Ground.
Do.....	Unknown.....	Martha.
Do.....	Unknown.....	(Mrs.) Aphia Salisbury Rich and Baby Edward.
Do.....	Unknown.....	Twenty-two Houses and a Church.
Do.....	Unknown.....	Village by the River.

SCULPTURE

Lessing J. Rosenwald.....	Daumier.....	Le Confident.
Do.....	Daumier.....	Le Représentant.

PRINTS AND DRAWINGS

During the year Lessing J. Rosenwald increased his gift to the Gallery by 198 additional prints and drawings. Four etchings by Breitner were given to the Gallery by the Rijksmuseum, The Netherlands. Two prints were also given by Mrs. Andrew G. Carey to be added to the Addie Burr Clark Memorial Collection.

OTHER GIFTS

Gifts of money were made during the fiscal year 1959 by the Old Dominion Foundation, Avalon Foundation, Mr. and Mrs. W. Randolph Burgess, Mrs. Tracy C. Dickson, Jr., and James E. Boudreau.

EXCHANGE OF WORKS OF ART

In exchange for five paintings, the Samuel H. Kress Foundation gave the National Gallery of Art the following notable paintings:

<i>Artist</i>	<i>Title</i>
Master of Flémalle and Assistants.	Madonna and Child with Saints in the Enclosed Garden.
El Greco-----	The Holy Family.
Cranach-----	Portrait of a Man.
Cranach-----	Portrait of a Woman.
Koerbecke-----	The Ascension.
Veronese-----	The Annunciation.

WORKS OF ART ON LOAN

The following works of art were received on loan by the Gallery:

<i>From</i>	<i>Artist</i>	<i>Title</i>
Chester Dale, New York, N.Y.	Vuillard-----	The Visit.
Do-----	Bakst-----	Ida Rubenstein.
Do-----	Monet-----	The Seine at Giverny.
Do-----	Bellocs-----	Blue Morning.
Do-----	Domergue-----	Mrs. Dale.
Do-----	Gros-----	Dr. Vignardonne.
Col. and Mrs. Edgar W. Garbisch, New York, N.Y.	Earl-----	Mrs. Noah Smith and Her Five Children.
Mr. and Mrs. Carleton Mitchell, Annapolis, Md.	Van Gogh-----	The Stevedores.
Do-----	Cézanne-----	Man with Crossed Arms.
The Samuel H. Kress Foundation, New York, N.Y.	Massys-----	Salvator Mundi.
Do-----	Magnasco-----	Bay with Shipwreck.
Do-----	Correggio-----	Salvator Mundi.

WORKS OF ART ON LOAN RETURNED

The following works of art on loan were returned during the fiscal year:

<i>To</i>	<i>Artist</i>	<i>Title</i>
The Samuel H. Kress Foundation, New York, N.Y.	Ferrucci-----	Madonna and Child.
Do-----	Tino di Camaino---	Madonna and Child.
Do-----	Pintoricchio-----	Madonna and Child.
Do-----	Sienese School-----	Madonna and Child with St. Bartholomew and St. John the Baptist.
Do-----	Neroccio de' Landi.	The Battle of Actium.
Do-----	Francesco di Giorgio.	The Visit of Cleopatra to Anthony.
Do-----	Master of the Jarves Cassoni.	The Triumph of Chastity.
Do-----	Guariento-----	Madonna and Child with Four Saints.
Do-----	Segna di Buonaventura.	Madonna and Child.
Do-----	Catena-----	Portrait of a Woman.
Do-----	Veronese-----	The Baptism of Christ.
Do-----	Botticelli-----	Madonna and Child.
Do-----	Bonfigli-----	Madonna and Child Enthroned.
Do-----	Rigaud-----	President Hébert.

<i>From</i>	<i>Artist</i>	<i>Title</i>
Chester Dale, New York, N.Y.	Derain.....	Portrait of a Girl.
Do.....	Flemish School XVI Century.	Portrait of a Woman.
Do.....	German School XVI Century.	Portrait of a Girl.
Do.....	Pisanello, Style of..	Portrait of a Woman.
Arnold W. Knauth II, Rockport, Mass.	Copley.....	Epes Sargent.
Robert Woods Bliss, Washington, D.C.	19 objects of Pre-Columbian Art.	

WORKS OF ART LENT

During the fiscal year the Gallery lent the following works of art for exhibition purposes:

<i>To</i>	<i>Artist</i>	<i>Title</i>
The Metropolitan Museum of Art, New York, N.Y.	Homer.....	Breezing Up.
Do.....	Homer.....	Hound and Hunter.
Do.....	Homer.....	Right and Left.
Do.....	Boucher.....	Tête-à-Tête (drawing).
Do.....	Moreau le Jeune...	Oui ou Non (drawing).
Museum of Fine Arts, Boston, Mass.	Homer.....	Breezing Up.
Do.....	Homer.....	Hound and Hunter.
Do.....	Homer.....	Right and Left.
Boymans Museum, Rotterdam, and the Orangerie, Paris.	Boucher.....	Tête-à-Tête (drawing).
Do.....	Moreau le Jeune...	Oui ou Non (drawing).
Westmoreland County Museum, Greensburg, Pa.	Park.....	Flax Scutching Bee.
Pennsylvania Historical Museum Commission, Harrisburg, Pa.	Eichholtz.....	Mrs. Phoebe Freeman.
Do.....	Eichholtz.....	James P. Smith.
Do.....	Eichholtz.....	Henry Eichholtz Leman.
Do.....	Eichholtz.....	William Clark Frazer.
Chatham College, Pittsburgh, Pa.	Copley.....	The Death of the Earl of Chatham.
Birmingham Museum of Art, Birmingham, Ala.	Stuart.....	George Washington (Vaughan-Sinclair).
Smallwood Foundation, Inc., Faulkner, Md.	Pine.....	General William Smallwood.
U.S. Supreme Court, Washington, D.C.	George Cuitt, the Younger.	Easby Abbey, near Richmond.
Woodlawn Plantation, Mount Vernon, Va.	Polk.....	General Washington at Princeton.

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year 1959:

- Etchings and Lithographs by Redon, from the Rosenwald collection. July 17, 1958, through December 7, 1958.
- Drawings and Prints by Rembrandt, from the Rosenwald and Widener collections. August 1, 1958, through September 21, 1958.
- Dutch Drawings—Masterpieces from Five Centuries, a special loan exhibition of 148 Dutch drawings, the most important ever shown in this country. October 5, 1958, through October 26, 1958.
- Winslow Homer—A Retrospective Exhibition, the Gallery's second one-man show in honor of a leading American painter. November 23, 1958, through January 4, 1959.
- Christmas Prints, gift of W. G. Russell Allen and from the Rosenwald collection. December 8, 1958, through March 23, 1959.
- Whistler Etchings, gift of Mr. and Mrs. J. Watson Webb. March 23, 1959, through June 23, 1959.
- Masterpieces of Impressionist and Post-Impressionist Painting, loan exhibition of French 19th-century paintings from private collections, celebrating the 50th anniversary of the founding of the American Federation of Arts and honoring the meetings of the International Chamber of Commerce. April 25, 1959, through May 24, 1959.
- Etchings and Mezzotints from Turner's Liber Studiorum, gift of Miss Ellen T. Bullard and from the Rosenwald collection. June 25, 1959, to continue into the next fiscal year.

TRAVELING EXHIBITIONS

Rosenwald collection.—Special exhibitions of prints from the Rosenwald collection were circulated to the following places during the fiscal year 1959:

- Smithsonian Traveling Exhibition Service, Washington, D.C.:
 - Contemporary German Prints. Exhibition tour extended through the fiscal year 1959. (Tour started October 1956.)
 - George Bellows—Prints and Drawings. 19 prints. Continued until January 30, 1959. (Tour started March 1957.)
- American Federation of Arts, New York, N.Y.:
 - The Life of Christ in Prints. 50 prints. Continued until February 10, 1959. (Tour started October 1957.)
- Arts Council of Great Britain:
 - Two prints by Hayter lent to a touring exhibition of Hayter's work starting in the fiscal year 1958 and continuing through July 1958.
- Museum of Art of Ogunquit, Maine:
 - Fourteen prints and drawings by Mary Cassatt. Exhibition starting in the fiscal year 1958 and continuing through the first week of September 1958.
- Boston Museum of Fine Arts, Boston, Mass.:
 - Daumier Anniversary Exhibition. 8 drawings and 35 prints by Daumier; also 8 bronzes by Daumier given by Mr. Rosenwald. July 1 through October 1, 1958.

National Museum of Modern Art, Mexico City, Mexico :

Inaugural Exhibition. 50 modern prints. September 1958 through April 1959.

Marion Koogler McNay Art Institute, San Antonio, Tex. :

Twenty-nine prints by Picasso. September and October 1958.

Huntington Library, San Marino, Calif. :

Five Daumier busts in Rosenwald Collection. August through October 1958.

Sunday School Board, Southern Baptist Convention, Nashville, Tenn. :

Twenty prints. September 10 to November 10, 1958.

St. George's School, Newport, R.I. :

Fourteen prints. October 15 through November 15, 1958.

Los Angeles County Museum, Los Angeles, Calif. :

Exhibition of Daumier lithographs and sculpture. 1 woodblock, 5 bronzes, 25 prints and drawings. November and December 1958.

Smithsonian Traveling Exhibition Service, Washington, D.C. :

Dutch Drawing Exhibition. One Dutch miniature. November 1958 through April 1959.

Detroit Institute of Arts, Detroit, Mich. :

Decorative Arts of the Italian Renaissance. One engraving. November 17, 1958 through January 6, 1959.

Everhart Museum, Scranton, Pa. :

Christmas Exhibition. 20 prints. Last week of November through December 1958.

Isaac Delgado Museum of Art, New Orleans, La. :

Life of Christ. 52 prints. December 7 through December 28, 1958.

The University of Nebraska Art Galleries, Lincoln, Nebr. :

Twenty-six prints. January 16 through February 13, 1959.

The University of Kansas Museum, Lawrence, Kans. :

Two prints. January 18 through March 1, 1959.

Metropolitan Museum of Art, New York, N.Y. :

Homer Exhibition. One lithograph by Homer. January 29 through March 8, 1959.

Art Institute of Chicago, Chicago, Ill. :

Gauguin Exhibition. Two monotypes by Gauguin. February and March 1959.

Notre Dame University, Notre Dame, Ind. :

Twenty-five prints. February 15 through April 5, 1959.

Mary Washington College of the University of Virginia, Fredericksburg, Va. :

Seventeen prints illustrating antique musical instruments. March 10 through March 31, 1959.

Metropolitan Museum of Art, New York, N.Y. :

Gauguin Exhibition. Two monotypes by Gauguin. April through May 1959.

Hillel Foundation at Pennsylvania State University, State College, Pa. :

Twenty-six prints on biblical themes. April 1 through April 15, 1959.

Corcoran Gallery of Art, Washington, D.C. :

The American Muse. One Audubon print. April 3 through May 17, 1959.

Gallaudet College, Washington, D.C. :

Three prints by Cadwallader Washburn. April 11 through June 8, 1959.

Virginia Museum of Fine Arts, Richmond, Va. :

Twenty-four prints with subjects related to the law for an exhibition commemorating the introduction of Common Law in the Colonies. May 14 through June 14, 1959.

Index of American Design.—During the fiscal year 1959, 27 traveling exhibitions (including 1,498 plates) with 44 bookings were circulated to Germany and the following States:

<i>State</i>	<i>Number of exhibitions</i>	<i>State</i>	<i>Number of exhibitions</i>
Alabama.....	1	North Carolina.....	1
Connecticut.....	2	Ohio.....	4
District of Columbia.....	2	Pennsylvania.....	7
Florida.....	2	Rhode Island.....	1
Indiana.....	1	Tennessee.....	1
Iowa.....	2	Texas.....	4
Maryland.....	1	Utah.....	3
Minnesota.....	1	Virginia.....	8
New York.....	1	West Virginia.....	1

CURATORIAL ACTIVITIES

Under the direction of Dr. Perry B. Cott, chief curator, the curatorial department accessioned 238 gifts to the Gallery during the fiscal year 1959. Advice was given regarding 381 works of art brought to the Gallery for expert opinion and 18 visits to collections were made by members of the staff in connection with offers of gifts. About 2,200 inquiries requiring research were answered verbally and by letter.

William P. Campbell, curator of painting, lectured on Early American Masterpieces in the National Gallery of Art at the Williamsburg Antiques Forum.

During the year members of the curatorial staff assisted in the judging of the following art exhibitions: Dr. Fern Rusk Shapley: *Conservative Contemporary Art* at the State Fair in Birmingham, Ala., and *Virginia Artists* at Vienna, Va.; Dr. H. Lester Cooke: Exhibitions sponsored by the Waterford Art Society, Virginia, Wilmington Society of the Fine Arts, and the USIA exhibition of Washington artists; Thomas P. Baird: Delmarva Chicken Festival, Dover, Del.; Ralph T. Coe: Exhibition held at The Plains, Va.

The Richter Archives received and cataloged over 700 photographs on exchange from museums here and abroad, and 3,055 photographs were purchased for the Richter Archives.

RESTORATION

Francis Sullivan, resident restorer of the Gallery, made regular and systematic inspection of all works of art in the Gallery, and periodically removed dust and bloom as required. He relined 11 paintings and gave special treatment to 38 paintings and 2 pieces of sculpture. Nineteen paintings were X-rayed as an aid in research. Experiments were continued with synthetic varnishes, and a fluores-

cent light rack was built to test the fading of paints and pigments in cooperation with the Mellon Institute of Industrial Research, Pittsburgh, Pa. In September, Mr. Sullivan attended a seminar held in Boston, Mass., on "Application of Science in Examination of Works of Art." In the spring he also made trips to New York, Bryn Athyn, Pa., and Annapolis, Md., to supervise the collecting and return of paintings for the exhibition "Masterpieces of Impressionist and Post-Impressionist Painting." Technical advice on condition and care of paintings was given when works of art were brought to the Gallery, and such technical information as could be given when requested by the public. He inspected all Gallery paintings on loan in Government buildings in Washington, and also gave advice on the special treatment of works of art belonging to Government agencies, including the Capitol, the White House, the Supreme Court, the State Department, the Treasury, the Department of the Interior, the Maritime Commission, the Smithsonian Institution, and the Freer Gallery of Art.

PUBLICATIONS

Dr. Perry B. Cott, chief curator, contributed an article entitled "A Note on Houdon's Bust of Diana" to *Studies in the History of Art* dedicated to William E. Suida on his 80th birthday, 1959. He also wrote an article for the *World Book Encyclopedia* on the "Art Museum."

Dr. Fern Rusk Shapley, assistant chief curator, also contributed an article entitled "Baldassare d' Este and a Portrait of Francesco II Gonzaga" to *Studies in the History of Art* dedicated to William E. Suida.

Dr. H. Lester Cooke, museum curator, wrote the following articles: "The Art of Edward Hopper," *America Illustrated*, 1959, No. 32; "The Art of George Bellows," *American Magazine*, May 1959; and the introduction to a catalog of an exhibition of Washington artists sent to Europe by USIA.

Ralph T. Coe, museum curator, contributed an article entitled "Impressionists in Washington" to the *Burlington Magazine*, June 1959.

During the fiscal year 1959 the Publications Fund published one new 11- by 14-inch color reproduction and eight new color and five new black-and-white Christmas cards. A large pochoir reproduction of a picture of the National Gallery of Art building was published by an outside publisher and was placed on sale by the fund. Fifteen new 2- by 2-inch color-slide subjects were added to the selection available, and two more sets of slides were issued.

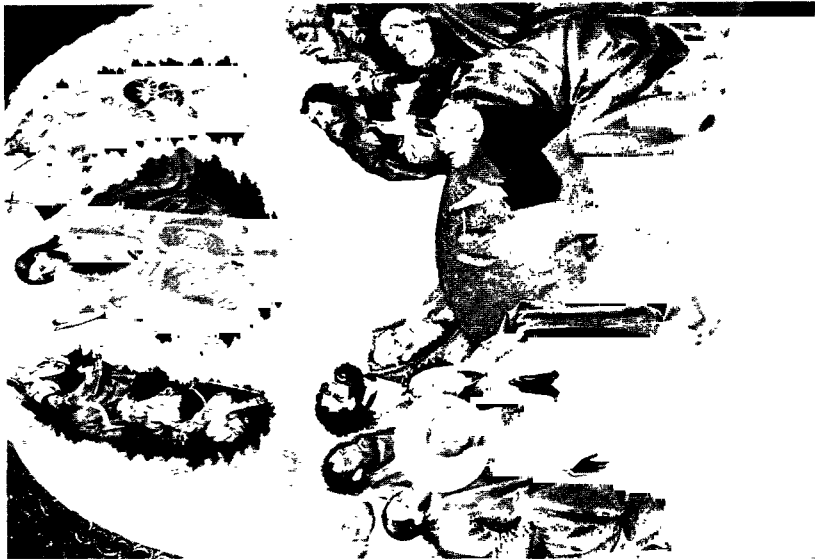
Color plates of five new subjects for 11- by 14-inch prints were completed during the year, and, in addition, work was begun on color



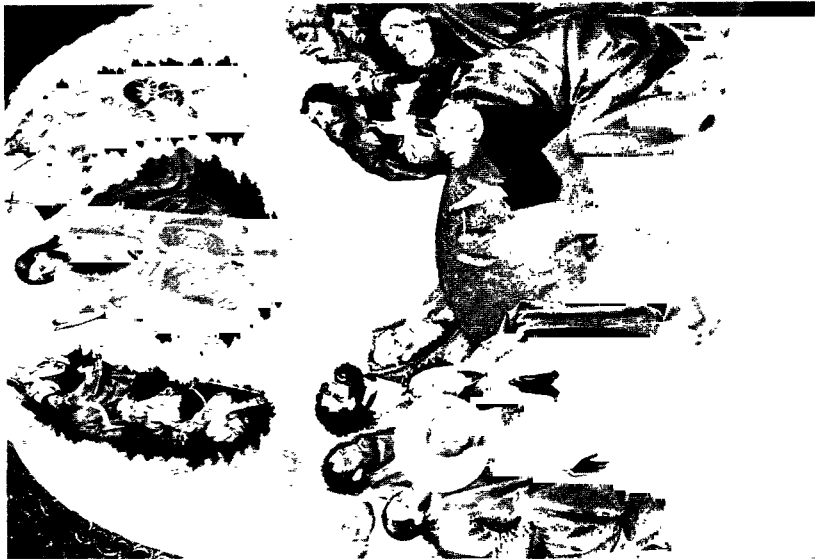
1. The Meeting of Abraham and Melchizedek. Peter Paul Rubens Gift of Syma Busiel, National Gallery of Art



2. Madonna and Child with Saints in the Enclosed Gardens: Master of Flémalle and Assistants. Samuel H. Kress Collection, National Gallery of Art.



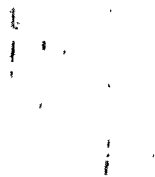
1. The Annunciation: Paolo Veronese. Samuel H. Kress Collection, National Gallery of Art.



2. The Ascension: Johann Korbbecke. Samuel H. Kress Collection, National Gallery of Art.

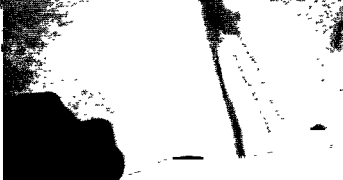


The Holy Family: El Greco. Samuel H. Kress Collection, National Gallery of Art.



1600

1. Epes Sargent; John Singleton Copley. Gift of Avalon Foundation, National Gallery of Art.



2. The Tragedian (portrait of Bouvière as Hamlet); Edouard Manet. Gift of Mrs Edith Stuyvesant Gerry, National Gallery of Art.

plates for a series of booklets to be issued by the Publications Fund on the schools of painting represented in the Gallery.

The publications sales rooms operated by the Publications Fund enjoyed their busiest year, serving 184,254 individuals, organizations, etc.

EDUCATIONAL PROGRAM

The program of the Educational Office was carried out under the supervision of Dr. Raymond S. Stites, curator in charge of educational work, and his staff, who lectured and conducted tours in the Gallery on the works of art in its collections.

The attendance for the general tours, Tours of the Week, and Picture of the Week talks totaled 40,532 persons; while that of the auditorium lectures on Sunday afternoon totaled 14,515 persons.

Tours, lectures, and conferences were arranged by special appointment for 340 groups and individuals. The total number of persons served in this manner was 11,585, an increase over last year of 3,488 persons. These special appointments were made for such groups as the various governmental agencies, educators (both foreign and American), religious groups, Girl Scouts, 4-H Clubs, convention groups, and members of the radio and television industry.

The program for the training of volunteer docents continued, and during the fiscal year 1959 special instruction was given to 100 women under the general supervision of the curator in charge of educational work. By special arrangement with the school systems of the District of Columbia and surrounding counties of Maryland and Virginia these women conducted tours for 1,546 classes with a total of 40,355 children—an increase over last year of 7,807 children visiting the National Gallery.

The staff of the Educational Office delivered 23 lectures in the auditorium on Sunday afternoons and 24 lectures were given by guest speakers. During the month of April and the first two Sundays in May, the Eighth Annual Series of the A. W. Mellon Lectures in the Fine Arts was delivered by the noted sculptor Naum Gabo, whose subject was "A Sculptor's View of the Fine Arts."

The Educational Office continued to circulate the nine sets of traveling exhibitions to schools, clubs, libraries, and universities throughout the country, free of charge except for transportation costs. These were viewed by a total of 20,000 persons during the year. Fifteen copies of the old National Gallery of Art film "Your National Gallery of Art" were borrowed 34 times through distribution centers, and the new film "Art in the Western World" was borrowed 26 times by local borrowers.

The Educational Office continued the sale of slide strips, and during the year a total of 80 sets were sold. The sale of the filmstrip "The Art of the Florentine Golden Age in the National Gallery of Art" totaled 30 sets.

A total of 1,750 slides were added to the slide collections during the year, and the slide library now contains 37,492 slides. A total of 10,982 slides were lent to 378 borrowers and seen by approximately 11,340 viewers. There was an increase of 143 borrowers over last year, and a total of 3,743 more slides lent. A number of slide lecture sets with text are available for loan.

Members of the staff prepared 6 more leaflets on works of art in individual galleries, and prepared mimeographed material for school groups, as well as undertaking the preparation of three illustrated 27-page booklets for sale at the publications sales rooms.

A printed calendar of events announcing all Gallery activities and publications was prepared by the Educational Office and distributed monthly to a mailing list of 6,800 names. This is an increase over last year of 1,100 names.

The staff members prepared and delivered twenty-nine 10-minute talks over station WGMS during intermission of the National Gallery of Art concerts broadcasts.

The curator in charge of educational work delivered lectures to several university, church, and club groups, gave two talks over WMAL-TV for the National Council of Churches, appeared on TV in Providence, R.I., in a lecture on American art, and judged an art exhibition at the Navy Department.

Grose Evans taught an evening course at George Washington University, delivered a number of outside lectures, and acted as judge for several art contests in the area.

Margaret Bouton taught evening courses in art at American University.

Dorothea Michelson delivered a talk at the National Housing Center.

Hugh Broadley taught an evening course in American art at American University.

LIBRARY

Important acquisitions to the library, recorded by Miss Ruth E. Carlson, librarian, and her staff, included 607 books, pamphlets, periodicals, subscriptions, and a group of 7,998 photographs purchased from private funds.

A total of 44 books and subscriptions were purchased from Government funds made available for this purpose. Gifts to the library included 773 books and pamphlets; 1,024 books, pamphlets, period-

icals, and bulletins were received on exchange from other institutions. During the fiscal year the library cataloged 3,307 publications, and 1,984 periodicals were recorded; 12,177 catalog cards were filed. The library borrowed 1,385 books on interlibrary loan; the Library of Congress lent 1,333 books.

The library is the depository for photographs of the works of art in the National Gallery of Art's collections. A stock of reproductions is maintained for use in research, for exchange with other institutions, and for sale to interested individuals. Approximately 6,300 photographs were received and processed in the library during the year. The library filled 1,143 orders for these photographs. Sales to the general public amounted to \$1,195, covering about 1,600 photographs. There were 303 permits for reproduction of 783 subjects processed in the library.

INDEX OF AMERICAN DESIGN

During the fiscal year the work of the Index continued as usual, under the direction of Dr. Erwin O. Christensen, curator. Twenty sets (1,020 slides) of color slides in 65 bookings were circulated throughout the country. Regular sets were lent for lecture and study purposes. Notes were completed for one additional set of slides on furniture. Three new lectures were completed on Index material, and 1,003 photographs of Index material were used for exhibition and study purposes, as well as for publicity, and purchase by the public. The photographic file of the Index material has been increased by 1,650 prints. Approximately 406 persons studied Index material for research purposes, and to gather material for publication and design.

Dr. Christensen continued to participate in the orientation program of the USIA personnel. The card-file index of the Index renderings was completed last year and an inventory of all photographs was begun. The curator of the Index prepared a report on the completion of the Index.

In all, 357 photographs of New England gravestone carvings, dating from 1653 to 1810, and 5 photographs of wood statues were given to the Gallery by Saul Ludwig of Montclair, N.J., and Mrs. Hugh De Witt of Stanford, Calif., respectively, for the Index of American Design.

MAINTENANCE OF THE BUILDING AND GROUNDS

The Gallery building, the mechanical equipment, and its grounds were maintained at the established standards throughout the year, under the direction of Ernest R. Feidler, administrator, and his staff.

Lectour, the electronic guide system, was installed in 10 additional galleries. Several of the installations were experimental in that the electronic guide system was introduced in adjacent galleries. Heretofore, in similar installations elsewhere and in the National Gallery of Art, service in adjacent galleries was deemed impracticable because of "crosstalk." This problem was solved in the new installations made during this past fiscal year.

The roofing over the Seventh and Fourth Street entrances and around the base of the dome, which had begun to deteriorate after 19 years of service, was replaced with roofing of improved design.

Permanent and improved floodlighting on the north portico and adjacent to the flagpoles replaced the temporary lighting developed for the 15th anniversary of the Gallery in 1956. This permanent floodlighting illuminates the central portion of the building on the north side.

The A.D.T. Aero Fire Alarm System was extended to the registrar's storeroom.

There was continued expansion of the Gallery's horticulture program with the result that extraordinary displays of flowering plants were available for the Christmas and Easter seasons and several important night openings.

LECTOUR

Lectour was installed and used successfully in two special exhibitions, and one foreign-language broadcast was prepared for a special group visit.

Lectour was used by 72,793 Gallery visitors during the fiscal year 1959. The system is being used progressively more extensively by visitors, as evidenced by the fact that in the last month of the fiscal year 1958 the percentage of visitors using Lectour was 6.3 percent, whereas the latter part of this year the percentage rose to 9.7 percent.

OTHER ACTIVITIES

Forty Sunday-evening concerts were given during the fiscal year in the east garden court, including nine concerts by the National Gallery of Art Orchestra under the direction of Richard Bales, two of which were made possible by the Music Performance Trust Fund of the American Federation of Musicians. A string orchestra under Mr. Bales's direction furnished music during the opening of the Dutch Exhibition on October 4, 1958, and during the opening of the Winslow Homer Exhibition on November 22, 1958. The National Gallery of Art orchestra with the Church of the Reformation cantata choir presented Mr. Bales's two cantatas, "The Confederacy" and "The Union," at the Watergate on July 30, 1958. On June 3, 1959, the National Gallery orchestra presented a concert at the Watergate in honor of the Governor of Casablanca (both concerts were paid for

by the Music Performance Trust Fund of the American Federation of Musicians). Mr. Bales appeared as guest conductor at a number of concerts in several cities throughout the United States during the year. Special concerts were held to commemorate United Nations Day and the Lincoln Sesquicentennial.

Four Sunday evenings during May 1959 were devoted to the Gallery's 16th American Music Festival. All concerts were broadcast in their entirety in stereophonic sound by station WGMS-AM and FM, Washington. The Voice of America regularly received portions of the Sunday evening concerts for transmission overseas. The intermissions during Sunday evening concerts featured discussions by members of the Educational Office staff and Mr. Bales.

During the fiscal year, 4,103 copies of 14 press releases in connection with the Gallery's activities were approved and issued by Director John Walker. In all, 148 permits to copy and 121 permits to photograph works of art in the Gallery were also issued.

During the fiscal year, in response to requests from Senators and Congressmen, 9,872 copies of the pamphlet "A Cordial Invitation from the Director" and 9,636 copies of the National Gallery of Art Information Booklet were sent for distribution to their constituents; 29,800 copies of "A Cordial Invitation from the Director" were sent to various organizations holding conventions in the Washington area.

During this fiscal year, the slide project begun in the fiscal year 1958 was carried to completion and sets of 500 color slides were sent to 114 colleges and universities having departments in the History of Art, and to museums having slide-lending services. This program was initiated in order to make slides of the works of art in the National Gallery of Art available in color at a minimum cost.

Henry B. Beville, the Gallery's photographer, and his staff processed 13,681 prints, 438 black-and-white slides, 1,121 color slides, 1,508 black-and-white negatives, 175 sets of color-separation negatives, 345 color transparencies, 6 infrared and 2 ultraviolet photographs during the fiscal year.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit of the private funds of the Gallery will be made for the fiscal year ended June 30, 1959, by Price Waterhouse & Co., public accountants, and the certificate of that company on its examination of the accounting records maintained for such funds will be forwarded to the Gallery.

Respectfully submitted,

HUNTINGTON CAIRNS, *Secretary.*

Dr. LEONARD CARMICHAEL

Secretary, Smithsonian Institution.

Report on the Library

SIR: I have the honor to submit the following report on the activities of the Smithsonian library for the fiscal year ended June 30, 1959:

Of the 52,669 publications received in the library, 2,706 were books and periodicals that could not be obtained in exchange. A special effort was made to acquire some of the much-needed reference materials that could not be obtained in the past. Publications were acquired to fill in special subject areas where adequate source materials were missing. Exchange relations with learned societies and scientific establishments both in this country and abroad continued to provide their serials and monographs which comprise the backbone of the library's collection. New exchanges arranged this year totaled 159, to be added to the vast number already established. Special requests for 2,359 publications were made to issuing societies and organizations for back issues of publications needed for completing sets in our collections. Books and periodicals were acquired for the Canal Zone Biological Area and also for the Astrophysical Observatory in Cambridge, Mass.

Recommendations for the acquisition of materials are of great importance in enriching the collections. Many significant gifts also come to the library from interested individuals including members and friends of the Smithsonian staff. Gifts of special note included "Voices from the Flowery Kingdom," from Mrs. Lucille Nott; 327 issues of philatelic journals from Alexander Halperson; 50 issues of the *Connoisseur*, from Fred J. P. Chitty; 3 volumes on Indian dancing by Leila Row Dayal; "Grundzuge der zoologischen Mikropaläontologie," Band 1, by Vladimir Pokorný.

Controlling the vast intake of publications each year requires the efforts of the entire staff in evaluating the materials for retention and in making them readily available for use. Lack of adequate space necessitates the daily sorting and shipping of all extraneous and duplicate publications to other agencies.

Beginning July 1, 1958, all publications forwarded to the Library of Congress were sent by transfer instead of being specifically designated for the Smithsonian Deposit, thus eliminating unnecessary recordkeeping on the part of both organizations. Publications sent to this organization totaled 20,558, many of which were continuations

of serials and monographs that have been received regularly in exchange since their first date of publication. To the National Library of Medicine were sent 2,378 publications, and to other Government libraries 714 items.

The catalog section cataloged and classified 4,082 books and pamphlets, entered 24,933 periodicals, and filed 45,485 cards. In spite of being short staffed and having an increased acquisitions program, the efforts of the catalogers to organize and plan their work have kept the bulk of the material moving. Efficient library service depends on a good catalog, and good cataloging practice is a basic requirement. The large number of uncataloged publications throughout the Institution remains a major problem. The scientific and technical nature of these publications, many of which are in foreign languages, requires scholarly treatment in processing.

The binding program continued to show vast improvements in the preservation and conservation of our valuable research materials. Through a waiver from the Government Printing Office, 8,800 volumes were bound or re-bound by a commercial binder under contract. A skilled bindery assistant repaired or hand-bound 1,851 volumes of materials not suitable to send to a binder. A special project is underway to put call-number labels on all the library materials. This will facilitate the shelving and locating of books and periodicals by the staff and users as well.

The program of continuous weeding and discarding of unused and duplicate materials is still in effect. A total of 8,901 books, pamphlets, and periodicals was discarded.

The library is frequently called upon to translate correspondence and miscellaneous items into English. Members of the catalog section translated 214 items and provided reference assistance or translations of obscure words and phrases. The class in scientific Russian, taught by David Ray, is still in progress.

Demands on the staff of the reference and circulation section continued to be heavy. It is difficult to measure the various services the library gives in making its resources available to those who wish to make use of them. During the year 12,360 loans were made, plus 9,374 volumes sent to the sectional libraries for semipermanent file. Since no estimate can be made of how many times books and periodicals circulate within a section, the exact number of times library materials are consulted cannot be determined.

There were 1,158 volumes lent to Government, college, and university libraries; and 3,853 volumes were borrowed from other libraries, chiefly the Library of Congress.

Visitors to the library numbered 9,202 persons who consulted the reference books and periodicals in the main reading room. Visiting research scholars used the library's facilities for checking and verifying references, and librarians and scientists from other countries came to acquaint themselves with the collections. The library staff answered 20,799 reference questions, which in most cases required the consultation of many different publications. These queries are from individuals who either write, telephone, or come in person to the library, and always it is rewarding to be able to provide them with the desired information or refer them to an authoritative source.

Care of the collections includes the task of relieving crowding of the books and keeping them clean. The addition of 26 new cases in the stacks of the main library has provided additional shelf space for the growing accumulation. Vacuuming the books and washing the shelves are underway in this area, and routine cleaning schedules are in effect in other stack areas.

In September 1958, the branch library for the Museum of History and Technology began operation. This collection of books and journals formerly served the staff in the Arts and Industries Building. The initial phase of the project of cleaning and discarding unused materials has been completed. The specific task of making this into a working library is in progress with a shelf inventory started, a binding and repairing program underway, the acquiring of necessary source and reference books and missing journals in process. This library will in the future supply source materials on the historical and technical development of this country. In spite of numerous handicaps during the 9 months of operation, 3,498 reference questions were answered, 2,559 books were charged out, 999 volumes were sent to the bindery, and 1,042 persons who came to the library for service were assisted.

It has been possible for the library to acquire some long-needed equipment. New microfilm reading machines and a book-copying machine have increased the service and efficiency. Other items such as a new charge desk and catalog cases have improved the appearance of the library and the morale of the staff. The repainting of several of the rooms has enhanced the whole cleanup program. The value of these new improvements cannot be measured, but their total effect on individual performance is more than gratifying.

Professional members of the staff attended the annual conventions of both the Special Libraries Association and the American Library Association, where they took advantage of the specialized activities that pertained to the functions of this library.

SUMMARIZED STATISTICS

ACCESSIONS

	Volumes	Total recorded volumes, 1959
Smithsonian Deposit at the Library of Congress----	(*)	586, 722
Smithsonian main library (includes former office and museum libraries)-----	7, 421	323, 924
Astrophysical Observatory (includes Radiation and Organisms)-----	42	15, 078
Bureau of American Ethnology-----	33	37, 749
National Air Museum-----	19	577
National Collection of Fine Arts-----	19	14, 159
National Zoological Park-----	69	4, 287
Total-----	7, 603	982, 596

*20,558 publications were forwarded by transfer to the Library of Congress without the Smithsonian Deposit stamp.

Unbound volumes of periodicals and reprints and separates from serial publications, of which there are many thousands, have not been included in these totals.

EXCHANGES

New exchanges arranged-----	159
Specially requested publications received-----	2, 359

CATALOGING

Volumes cataloged-----	4, 082
Catalog cards filed-----	45, 485

PERIODICALS

Periodical parts entered-----	24, 933
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CIRCULATION

Loans of books and periodicals-----	21, 734
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Circulation in sectional libraries is not counted except in the Division of Insects.

BINDING AND REPAIR

Volumes sent to the bindery-----	8, 800
Volumes repaired in the library-----	1, 851

Respectfully submitted.

RUTH E. BLANCHARD, *Librarian.*

Dr. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Report on Publications

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches for the year ended June 30, 1959:

The publications of the Smithsonian Institution are issued partly from federally appropriated funds (Smithsonian Reports and publications of the National Museum, the Bureau of American Ethnology, and the Astrophysical Observatory) and partly from private endowment funds (Smithsonian Miscellaneous Collections, publications of the Freer Gallery of Art, and some special publications). The Institution also edits and publishes under the auspices of the Freer Gallery of Art the series *Ars Orientalis*, which appears under the joint imprint of the University of Michigan and the Smithsonian Institution. The third volume in this series was in press at the close of the year. In addition, the Smithsonian publishes a guidebook, a picture pamphlet, postcards and a postcard folder, a color-picture album, color slides, a filmstrip on Smithsonian exhibits, a coloring book for children, and popular publications on scientific and historical subjects related to its important exhibits and collections for sale to visitors. Through its publication program the Smithsonian endeavors to carry out its founder's expressed desire for the diffusion of knowledge.

During the year the Institution published 1 whole volume and 10 papers in the Miscellaneous Collections; 1 Annual Report of the Board of Regents and separates of 19 articles in the General Appendix; 1 Annual Report of the Secretary; 4 special publications; and reprints of 1 volume of Miscellaneous Collections and 1 special publication.

The U.S. National Museum issued 1 Annual Report, 4 Bulletins, 18 Proceedings papers, and 2 special publications.

The Bureau of American Ethnology issued one Annual Report and four Bulletins.

The Astrophysical Observatory issued seven numbers in the series *Smithsonian Contributions to Astrophysics*.

The National Collection of Fine Arts published three catalogs, and the Smithsonian Traveling Exhibition Service, under the National Collection of Fine Arts, published one catalog.

The Freer Gallery of Art issued one paper in its *Occasional Papers* series, and a revised edition of one pamphlet.

DISTRIBUTION

There were distributed 580,018 copies of publications and miscellaneous items. *Publications*: 34 Contributions to Knowledge, 23,886 Smithsonian Miscellaneous Collections, 8,725 Annual Report volumes and 22, 528 pamphlet copies of Report separates, 575 War Background Studies, 49,684 special publications, 93 reports of the Harriman Alaska Expedition, 52,700 publications of the National Museum, 27,721 publications of the Bureau of American Ethnology, 28,170 publications of the National Collection of Fine Arts, 583 publications of the Freer Gallery of Art, 14,951 publications of the Astrophysical Observatory, 1,581 reports of the American Historical Association, and 1,775 publications not issued by the Smithsonian Institution. *Miscellaneous items*: 4 sets of North American Wild Flowers and 34 Wild Flower prints, 57 Pitcher Plant volumes, 44,230 guide books, 19,293 picture pamphlets, 211,260 postcards and postcard folders, 19,414 color slides, 49,660 information leaflets, and 15 New Museum of History and Technology pamphlets. There were also distributed 366 statuettes, 2,670 Viewmaster reels, and 5 filmstrips and 4 filmstrip records.¹

SMITHSONIAN MISCELLANEOUS COLLECTIONS

In this series, under the immediate editorship of Ruth B. MacManus, there were issued one paper in volume 119, two papers in volume 135, two papers in volume 136, whole volume 137, four papers in volume 138, and one paper in volume 139, as follows:

Volume 119

No. 3. Mississippian fauna in northwestern Sonora, by William H. Easton, John E. Sanders, J. Brookes Knight, and Arthur K. Miller. 87 pp., 9 pls., 4 figs. (Publ. 4313.) Aug. 8, 1958. (\$1.35.)

Volume 135

No. 1. The customs and religion of the Ch'iang, by David Crockett Graham. 114 pp., 16 pls., 6 figs. (Publ. 4300.) Dec. 2, 1958. (\$2.)
No. 9. New American Paleozoic echinoids, by Porter M. Kier. 26 pp., 8 pls., 22 figs. (Publ. 4337.) Aug. 4, 1958. (75 cents.)

Volume 136

No. 1. A review of the middle and upper Eocene primates of North America, by C. Lewis Gazin. 112 pp., 14 pls. (Publ. 4340.) July 7, 1958. (\$1.75.)
No. 2. The journals of Daniel Noble Johnson (1822-1863), United States Navy, edited by Mendel L. Peterson. 268 pp., 16 pls. (Publ. 4375.) Apr. 2, 1959. (\$4.)

¹ Additional copies of the Institution's filmstrip and record, "Let's Visit the Smithsonian," were distributed through the Society for Visual Education, Chicago, Ill.

Volume 137

Studies in invertebrate morphology. Published in honor of Dr. Robert Evans Snodgrass on the occasion of his 84th birthday, July 5, 1959. 18 articles by various authors. 416 pp., 49 pls., 149 figs. (Publ. 4350.) [June 19] 1959. (\$7.50.)

Volume 138

No. 1. Pueblo del Arroyo, Chaco Canyon, New Mexico, by Neil M. Judd. 222 pp., 55 pls., 45 figs. (Publ. 4346.) June 26, 1959. (\$4.50.)

No. 2. Evolution of arthropod mechanisms, by R. E. Snodgrass. 77 pp., 24 figs. (Publ. 4347.) Nov. 28, 1958. (85 cents.)

No. 3. Long-range weather forecasting, by C. G. Abbot. 19 pp., 11 figs. (Publ. 4352.) Feb. 16, 1959. (30 cents.)

No. 4. Birds of the Pleistocene in North America, by Alexander Wetmore. 24 pp. (Publ. 4353.) Jan. 15, 1959. (35 cents.)

Volume 139

No. 1. The oldest known reptile, *Eosauravus copei* Williston, by Frank E. Peabody. 14 pp., 1 pl., 3 figs. (Publ. 4377.) May 7, 1959. (50 cents.)

SMITHSONIAN ANNUAL REPORTS

REPORT FOR 1957

The complete volume of the Annual Report of the Board of Regents for 1957 was received from the printer on October 10, 1958:

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ended June 30, 1957. x+499 pp., 74 pls., 32 figs. (Publ. 4314.)

The general appendix contained the following papers (Publ. 4315-4333):

Science, technology, and society, by L. R. Hafstad.

United States Coast and Geodetic Survey, 1807-1957, by Elliott B. Roberts.

Cosmic rays from the sun, by Thomas Gold.

Meteors, by Fred L. Whipple.

The development of the planetarium in the United States, by Joseph Miles Chamberlain.

The development of radio astronomy, by Gerald S. Hawkins.

Jet streams, by R. Lee.

Pollen and spores and their use in geology, by Estella B. Leopold and Richard A. Scott.

The influence of man on soil fertility, by G. V. Jacks.

The land and people of the Guajira Peninsula, by Raymond E. Crist.

The nature of viruses, cancer, genes, and life, by Wendell M. Stanley.

Mystery of the red tide, by F. G. Walton Smith.

The return of the vanishing musk oxen, by Hartley H. T. Jackson.

Bamboo in the economy of Oriental peoples, by F. A. McClure.

Mechanizing the cotton harvest, by James H. Street.

Aniline dyes—their impact on biology and medicine, by Morris C. Leikind.

Causes and consequences of salt consumption, by Hans Kaunitz.

Roman garland sarcophagi from the quarries of Proconnesus (Marmara), by J. B. Ward Perkins.

Stone age skull surgery, by T. D. Stewart.

REPORT FOR 1958

The Report of the Secretary, which will form part of the Annual Report of the Board of Regents to Congress, was issued January 16, 1959:

Report of the Secretary and financial report of the Executive Committee of the Board of Regents for the year ended June 30, 1958. x+232 pp., 14 pls., 1 chart. (Publ. 4345.)

SPECIAL PUBLICATIONS

The gown of Mrs. Dwight D. Eisenhower, by Margaret Brown Klapthor. Supplement to "The Dresses of the First Ladies of the White House," Publ. 4060. 4 pp., 2 pls. [Sept. 26] 1958. (50 cents.)

Anthropology as a career, by William C. Sturtevant. 18 pp. (Publ. 4343.) July 25, 1958. (20 cents.)

List of Smithsonian publications available for distribution June 30, 1958, compiled by Eileen M. McCarthy. 54 pp. (Publ. 4344.) [Oct. 14] 1958.

First book of grasses, by Agnes Chase. Ed. 3, with revisions and additions of color plate and foreword by Leonard Carmichael. xix+127 pp., 1 pl., 94 figs. (Spec. Publ. 4351.) [Feb. 12] 1959. (\$3.)

REPRINTS

Smithsonian Meteorological Tables, Sixth Revised Edition, prepared by Robert J. List. First reprint. Smithsonian Miscellaneous Collections, vol. 114, Publ. 4014. xi+527 pp. [July 24] 1958. (\$4.)

Brief Guide to the Smithsonian Institution. 1958 rev. ed. Spec. Publ. 82 pp., illus. [Nov. 10] 1958. (25 cents.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum continued during the year under the immediate direction of John S. Lea, assistant chief of the division. The following publications were issued:

REPORT

The United States National Museum annual report for the year ended June 30, 1958. Pp. iv+150, illus. Jan. 16, 1959.

BULLETINS

193. Supplement 1. Publications of the United States National Museum, January 1947-June 1958. Pp. iii+16. Oct. 8, 1958.

212. Checklist of the millipeds of North America, by Ralph V. Chamberlin and Richard L. Hoffman. Pp. iii+236. Sept. 26, 1958.

214. Review of the parrotfishes, family Scaridae, by Leonard P. Schultz. Pp. v+143, 31 figs., 27 pls. Sept. 16, 1958.

216. Ichneumon-flies of America north of Mexico: 1. Subfamily Metopliinae, by Henry and Marjorie Townes. Pp. ix+318, 196 figs. Mar. 6, 1959.

PROCEEDINGS

Volume 106

Title page, table of contents, and index. Pp. i-vii, 589-615. June 8, 1959.

Volume 107

Title page, table of contents, and index. Pp. 1-v, 651-671. May 29, 1959.

Volume 108

- No. 3395. A review of some galerucine beetles with excised middle tibiae in the male, by Doris H. Blake. Pp. 59-101, 6 figs. July 16, 1958.
- No. 3398. A review of the copepod genus *Ridgecayia* (Calanoida) with descriptions of new species from the Dry Tortugas, Florida, by Mildred Stratton Wilson. Pp. 137-179, 37 figs. Aug. 11, 1958.
- No. 3399. Revision of the milliped genus *Pachydesmus* (Polydesmida: Xystodesmidae), by Richard L. Hoffman. Pp. 181-218, 12 figs. Aug. 20, 1958.
- No. 3400. A revision of the eels of the genus *Conger* with descriptions of four new species, by Robert H. Kanazawa. Pp. 219-267, 7 figs., 4 pls. Oct. 6, 1958.
- No. 3401. Three North American Cretaceous fishes, by David H. Dunkle. Pp. 269-277, 3 pls. Oct. 21, 1958.
- No. 3402. Taxonomy and nomenclature of three species of *Lonchura* (Aves: Estrildinae), by Kenneth C. Parkes. Pp. 279-293, 1 fig. Oct. 21, 1958.
- No. 3403. Rhizocephala of the family Peltogastridae parasitic on West Indian species of Galatheididae, by Edward G. Reinhard. Pp. 295-307, fig. 4, 1 pl. Nov. 20, 1958.
- No. 3404. Advances in our knowledge of the honey-guides, by Herbert Friedmann. Pp. 309-320. Oct. 21, 1958.
- No. 3405. Three new serranid fishes, genus *Pikea*, from the western Atlantic, by Leonard P. Schultz. Pp. 321-329, 2 figs. Nov. 17, 1958.
- No. 3406. The status of the lizard *Cnemidophorus perplexus* Baird and Girard (Teiidae), by T. Paul Maslin, Richard G. Beidleman, and Charles H. Lowe, Jr. Pp. 331-345. Dec. 31, 1958.
- No. 3407. Synopsis of the species of agromyzid leaf miners described from North America (Diptera), by Kenneth E. Frick. Pp. 347-465, 170 figs. Mar. 5, 1959.
- No. 3409. Scarab beetles of the genus *Bothynus* in the United States (Coleoptera: Scarabaeidae), by O. L. Cartwright. Pp. 515-541, 6 figs. Mar. 10, 1959.
- No. 3410. A further study of Micronesian polyclad flatworms, by Libby H. Hyman. Pp. 543-597, 17 figs. Mar. 6, 1959.

Volume 109

- No. 3411. A revision of the milliped genus *Brachoria* (Polydesmida: Xystodesmidae), by William T. Keeton. Pp. 1-58, 11 figs. Apr. 14, 1959.
- No. 3413. Notes on Aradidae in the U.S. National Museum (Hemiptera), I. Subfamily Calisiinae, by Nicholas A. Kormilev. Pp. 209-222, 18 figs. Apr. 20, 1959.
- No. 3414. Flies of the genus *Odinia* in the Western Hemisphere (Diptera: Odiniidae), by Curtis W. Sabrosky. Pp. 223-236, 1 pl. May 29, 1959.

SPECIAL PUBLICATIONS

- A handbook for employees. iii+40 pp., 27 figs. Dec. 24, 1958.
- Guard manual and regulations for the guard force. [8]+75 pp. June 1958.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau continued under the immediate direction of Mrs. Eloise B. Edelen. The following publications were issued:

ANNUAL REPORT

- Seventy-fifth Annual Report of the Bureau of American Ethnology, 1957-1958. 11+36 pp., 5 pls. 1959.

BULLETINS

- Bulletin 168. The Native Brotherhoods: Modern intertribal organizations on the Northwest coast, by Philip Drucker. iv+194 pp. October 1958.
- Bulletin 169. River Basin Surveys Papers Nos. 9-14. ix+392 pp., 73 pls., 13 figs., 9 maps. December 1958.
- No. 9. Archeological investigations in the Heart Butte Reservoir area, North Dakota, by Paul L. Cooper.
- No. 10. Archeological investigations at the Tuttle Creek Dam, Kansas, by Robert B. Cumming, Jr.
- No. 11. The Spain site (39LM301), a winter village in Fort Randall Reservoir, South Dakota, by Carlyle S. Smith and Roger T. Grange, Jr.
- No. 12. The Wilbanks site (9CK-5), Georgia, by William H. Sears.
- No. 13. Historic sites in and around the Jim Woodruff Reservoir area, Florida-Georgia, by Mark F. Boyd.
- No. 14. Six sites near the Chattahoochee River in the Jim Woodruff Reservoir area, Florida, by Ripley P. Bullen.
- Bulletin 170. Excavations at La Venta, Tabasco, 1955, by Philip Drucker, Robert F. Heizer, and Robert J. Squier. With appendixes by Jonas E. Gullberg, Garniss H. Curtis, and A. Starker Leopold. viii+312 pp., 63 pls., 82 figs. March 1959.
- Bulletin 171. The North Alaskan Eskimo: A study in ecology and society, by Robert F. Spencer. vi+490 pp., 9 pls., 2 figs., 4 maps. May 1959.

PUBLICATIONS OF THE ASTROPHYSICAL OBSERVATORY

The editorial work of the Smithsonian Astrophysical Observatory continued under the immediate direction of Ernest E. Biebighauser. The year's publications are as follows:

SMITHSONIAN CONTRIBUTIONS TO ASTROPHYSICS

Volume 2

- No. 11. The statistics of meteors in the earth's atmosphere, by Gerald S. Hawkins and Richard B. Southworth. Pp. 349-364, 5 figs. Aug. 5, 1958.
- No. 12. Granulation and oscillations of the solar atmosphere, by Charles Whitney. Pp. 365-376, 2 figs. July 29, 1958.
- No. 13. Optical properties of Saturn's rings: I. Transmission, by Allan F. Cook, II, and Fred A. Franklin. Pp. 377-383, 3 figs. Nov. 14, 1958.

Volume 3

- No. 1. The regression of the node of the quadrantids, by Gerald S. Hawkins and Richard B. Southworth. Pp. 1-5, 2 figs. Oct. 1, 1958.
- No. 2. Catalogs of meteor radiants, by Gerald S. Hawkins. Pp. 7-8, 3 figs. Sept. 26, 1958.
- No. 3. Papers on the solar constant: "The Constancy of the Solar Constant," by Theodore E. Sterne and Nannielou Dieter, 1 fig.; "On Sterne and Dieter's paper, 'The Constancy of the Solar Constant,'" by C. G. Abbot, 9 figs.; and "The solar constant," by L. B. Aldrich and W. H. Hoover. Pp. 9-24. Dec. 24, 1958.
- No. 4. Some sunspot and flare statistics, by Barbara Bell and Harold Glazer. Pp. 25-38, 3 figs. May 18, 1959.
- No. 5. The Doppler widths of solar absorption lines, by Barbara Bell and Alan Meltzer. Pp. 39-46. May 13, 1959.

PUBLICATIONS OF THE NATIONAL COLLECTION OF FINE ARTS

- Profiles of the time of James Monroe, 1758-1958. 13 pp., 1 pl. (Publ. 4348.) [Oct. 24] 1958.
 Henry Ward Ranger centennial exhibition, 1858-1958. 30 pp., 1 pl. (Publ. 4349.) [Dec. 1] 1958.
 Turn-of-the-century paintings from the William T. Evans collection. 8 pp. [Apr. 23] 1959.
 Smithsonian Institution Traveling Exhibitions, 1959-1960 catalog. 40 pp.

PUBLICATIONS OF THE FREER GALLERY OF ART

- The lohans and a bridge to heaven, by Wên Fong. Occas. Pap., vol. 3, No. 1, 64 pp., 18 pls., 1 fig. (Publ. 4305.) [Aug. 21] 1958. (\$1.00.)
 The Freer Gallery of Art of the Smithsonian Institution. 16 pp., 8 pls., 3 figs. Rev. ed. 1958.

REPORTS OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the association to the Secretary of the Smithsonian Institution and are by him communicated to Congress, as provided in the act of incorporation of the association. No reports were issued during the year.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the 60th Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, on January 7, 1959.

OTHER ACTIVITIES

During the year the Institution acquired, through a generous gift of the author, the remaining stock of the book "Composition of Scientific Words," by Dr. Roland W. Brown, former geologist of the U.S. Geological Survey. The volume, 882 pages in size, is subtitled "A Manual of Methods and a Lexicon of Materials for the Practice of Logotechnics." Published by the author in 1956, it is now being distributed by the Smithsonian.

The chief of the division continued to represent the Smithsonian Institution on the board of directors of the Greater Washington Educational Television Association, Inc., of which the Institution is a member.

Respectfully submitted.

PAUL H. OEHSER,
Chief, Editorial and Publications Division.

Dr. LEONARD CARMICHAEL,
Secretary, Smithsonian Institution.

Other Activities

LECTURES

In 1931 the Institution received a bequest from James Arthur, of New York City, a part of the income from which was to be used to endow an annual lecture on some aspect of the sun. The 25th Arthur lecture was delivered in the auditorium of the Natural History Building on the evening of October 23, 1958, by Dr. Leo Goldberg, director of the Observatory of the University of Michigan. This illustrated lecture, on the subject "Astronomy from Artificial Satellites," will be published in full in the general appendix of the Annual Report of the Board of Regents of the Smithsonian Institution for 1959.

Dr. Homer A. Thompson, professor of classical archeology, Institute for Advanced Study, Princeton, N.J., delivered a lecture on "Athenian Twilight" in the auditorium of the Natural History Building on the evening of December 2, 1958. This was sponsored jointly by the Smithsonian Institution and the Archaeological Institute of America.

Under the joint sponsorship of the Smithsonian Institution, the Anthropological Society of Washington, and the Netherland-America Foundation, Dr. J. Victor de Bruyn, adviser to the Netherlands Government on New Guinea affairs, lectured on "New Guinea Papuans Today and Tomorrow," on March 4, 1959, in the Natural History Building auditorium.

Grover Loening, aeronautical engineer and manufacturer and member of the advisory board of the National Air Museum, presented a lecture on "Lessons from the History of Flight" in the auditorium of the Natural History Building on May 18, 1959. This lecture is to be published in the general appendix of the Annual Report of the Board of Regents of the Smithsonian Institution for 1959.

H. Alan Lloyd, F.S.A., F.B.H.I., M.B.E., gave a lecture on "Pre-Renaissance Clocks and Their Influence" on May 20, 1959, in the auditorium of the Freer Gallery of Art, under the joint sponsorship of the Smithsonian Institution and the National Association of Watch and Clock Collectors.

Several lectures were also sponsored by the Freer Gallery of Art and the National Gallery of Art. These are listed in the reports of these bureaus.

SMITHSONIAN MUSEUM SERVICE

The Smithsonian Museum Service was established on October 21, 1958. G. Carroll Lindsay was appointed acting curator of the Service on the same date. He had served as assistant curator of ethnology from 1956 to 1957 and as associate curator of cultural history since 1957.

The Museum Service, operating under the Office of the Secretary, acts to coordinate the extension of the museum activities of the Institution with particular attention to the historic development of these activities and their relationship to the development of the entire Institution from its founding to the present time. The activity of the Museum Service includes the administration of Smithsonian cooperation with the volunteer docents of the Junior League of Washington, D.C. A more complete report of this activity for the 1958-59 season is carried in the report of the U.S. National Museum.

The Museum Service also provided assistance to professional and subprofessional individuals and groups visiting the museums of the Institution. Arrangements were made through the Museum Service for Smithsonian participation in the Joint Workshop on Use of Community Resources sponsored by the University of Maryland and George Washington University. Through the facilities of this workshop a 5-day program outlining the history of the Institution and the work of the various Smithsonian museum and research bureaus was presented to 41 graduate students from the participating universities. Assistance was also rendered to other college and university groups visiting the Institution, and to individuals from the United States and abroad, visiting or planning to visit the Smithsonian in a professional capacity.

The Museum Service carried out the arrangements for various Smithsonian public functions and events, including lectures and the opening of the new halls and exhibits. Mailing lists for invitations to these functions and events of the Institution were enlarged and reorganized, and the Smithsonian *Calendar of Events*, a monthly listing of exhibit openings, lectures, and other special events of the Institution, was prepared and distributed.

BIO-SCIENCES INFORMATION EXCHANGE

The Bio-Sciences Information Exchange, an agency operated under the Smithsonian Institution but financed by other Government agencies, is a clearinghouse for research in the life sciences.

Abstracts of current research are registered by investigators engaged in biological, medical, and psychological research and in limited aspects of research in the social sciences. Through an extensive system of subject indexing, these abstracts are provided upon request and

without charge to researchers in research institutions. Through this simple mechanism, the Exchange maintains a communication system which precedes publication and prevents unknowing duplication. For granting agencies and properly constituted committees it prepares extensive surveys of research in broad areas.

Owing to the worldwide interest in scientific information and to the increased funds for research in the bio-sciences, the Exchange has been authorized to install an electronic computer. During the year arrangements for the purchase of the machine and initial plans for its operation have been completed.

The Department of Defense has joined the other Federal agencies supporting the Exchange and has appointed Dr. Orr E. Reynolds, director, Office of Science, Office of the Director of Research and Engineering, as its representative on the governing board.

AVIATION EDUCATION INSTITUTE

The Institution cooperated with American University in conducting the First Aviation Education Institute for Science Teachers at the National Air Museum during the period July 1 to August 8, 1958. The project was made possible by a grant from the Link Foundation. Five teachers from the Washington, D.C., area completed the 6-week course and received university credits. The Aviation Education Institute is conducted at the Smithsonian's National Air Museum because of the unique facilities there, which include the National Aeronautical Collections, a wealth of historical information in the Museum's library and reference files, and the research guidance offered by Director Philip S. Hopkins and his curatorial staff.

Report of the Executive Committee of the Board of Regents of the Smithsonian Institution

For the Year Ended June 30, 1959

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN INSTITUTION

PARENT FUND

The original bequest of James Smithson was £104,960 8s 6d—\$508,318.46. Refunds of money expended in prosecution of the claim, freight, insurance, and other incidental expenses, together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of \$550,000.

The gift of James Smithson was "lent to the United States Treasury, at 6 per centum per annum interest" (20 USC. 54) and by the Act of March 12, 1894 (20 USC. 55) the Secretary of the Treasury was "authorized to receive into the Treasury, on the same terms as the original bequest of James Smithson, such sums as the Regents may, from time to time see fit to deposit, not exceeding, with the original bequest the sum of \$1,000,000."

The maximum of \$1,000,000 which the Smithsonian Institution was authorized to deposit in the Treasury of the United States was reached on January 11, 1917, by the deposit of \$2,000.

Under the above authority the amounts shown below are deposited in the United States Treasury and draw 6 percent interest:

	<i>Unrestricted funds</i>	<i>Income</i>
James Smithson.....	\$727, 640	\$43, 658. 40
Avery	14, 000	840. 00
Habel	500	30. 00
Hamilton	2, 500	150. 00
Hodgkins (general)	116, 000	6, 960. 00
Poore	26, 670	1, 600. 20
Rhees	590	35. 40
Sanford	1, 100	66. 00
Total	889, 000	53, 340. 00

	<i>Restricted funds</i>	<i>Income</i>
Hodgkins (specific) -----	\$100, 000	\$6, 000. 00
Reid -----	11, 000	660. 00
Total -----	111, 000	6, 660. 00
Grand total -----	1, 000, 000	60, 000. 00

In addition to the \$1,000,000 deposited in the Treasury of the United States there has been accumulated from income and bequests the sum of \$3,658,636.78 which has been invested and is carried on the books of the Institution as the Consolidated Fund, a policy approved by the Regents at their meeting on December 14, 1916.

CONSOLIDATED FUND

(Income for the unrestricted use of the Institution)

Fund	Investment 1959	Income 1959
Abbott, W. L., special.....	\$20, 443. 51	\$1, 036. 06
*Avery, Robert S., and Lydia.....	54, 200. 83	2, 746. 89
Gufts, royalties, gain on sale of securities.....	378, 877. 09	19, 201. 73
Hachenberg, George P., and Caroline.....	5, 518. 63	279. 71
*Hamilton, James.....	553. 91	28. 07
Hart, Gustavus E.....	608. 36	17. 16
Henry, Caroline.....	1, 659. 55	84. 12
Henry, Joseph, and Harriet A.....	67, 265. 84	3, 409. 04
*Hodgkins, Thomas G. (general).....	41, 567. 14	2, 106. 63
Morrow, Dwight W.....	106, 110. 34	5, 377. 69
Olmsted, Helen A.....	1, 099. 40	55. 73
*Poore, Lucy T., and George W.....	223, 330. 00	11, 207. 69
Porter, Henry Kirke.....	392, 988. 77	19, 916. 65
*Rhees, William Jones.....	649. 21	32. 91
*Sanford, George H.....	1, 221. 51	61. 92
*Smithson, James.....	1, 675. 21	84. 90
Witherspoon, Thomas A.....	177, 082. 45	8, 974. 62
Total.....	\$1, 474, 911. 75	\$74, 621. 72

*In addition to funds deposited in the United States Treasury.

CONSOLIDATED FUND

(Income restricted to specific use)

Fund	Investment 1959	Income 1959
Abbott, William L., for investigations in biology.....	\$143, 272. 84	\$7, 254. 54
Arthur, James, for investigations and study of the sun and annual lecture on same.....	54, 878. 86	2, 781. 31
Bacon, Virginia Purdy, for traveling scholarship to investigate fauna of countries other than the United States.....	68, 748. 24	3, 484. 16
Baird, Lucy H., for creating a memorial to Secretary Baird.....	33, 038. 26	1, 674. 39
Barney, Alice Pike, for collection of paintings and pastels and for encouragement of American artistic endeavor.....	39, 356. 91	1, 994. 65
Barstow, Frederick D., for purchase of animals for Zoological Park.....	1, 371. 87	69. 51

CONSOLIDATED FUND—Continued

Fund	Investment 1959	Income 1959
Canfield Collection, for increase and care of the Canfield collection of minerals.	\$52,482.58	\$2,659.86
Casey, Thomas L., for maintenance of the Casey collection and promotion of researches relating to Coleoptera.....	17,199.81	871.72
Chamberlain, Francis Lea, for increase and promotion of Isaac Lea collection of gems and mollusks.....	38,641.81	1,958.36
Dykes, Charles, for support in financial research.....	59,084.00	2,994.10
Eickemeyer, Florence Brevoort, for preservation and exhibition of the photographic collection of Rudolph Eickemeyer, Jr.....	14,915.03	755.93
Hanson, Martin Gustav and Caroline Runice, for some scientific work of the Institution, preferably in chemistry or medicine.....	12,198.67	618.21
Higbee, Harry, Memorial Fund, for general use of the Institution after the period of ten years from date of gift (1957).....	763.94	36.81
Hillyer, Virgil, for increase and care of Virgil Hillyer collection of lighting objects.....	9,018.34	457.04
Hitchcock, Albert S., for care of the Hitchcock Agrostological Library.....	2,165.26	109.75
Hrdlička, Aleš and Marie, to further researches in physical anthropology and publication in connection therewith.....	59,259.98	2,858.46
Hughes, Bruce, to found Hughes alcove.....	24,265.73	1,331.15
Loeb, Morris, for furtherance of knowledge in the exact sciences.....	119,591.06	6,060.94
Long, Annette and Edith C., for upkeep and preservation of Long collection of embroideries, laces, and textiles.....	745.07	37.74
Maxwell, Mary E., for care and exhibition of Maxwell collection.....	26,914.61	1,304.06
Myer, Catherine Walden, for purchase of first-class works of art for use and benefit of the National Collection of Fine Arts.....	27,717.08	1,404.72
Nelson, Edward W., for support of biological studies.....	30,515.84	1,546.55
Noyes, Frank B., for use in connection with the collection of dolls placed in the U.S. National Museum through the interest of Mr. and Mrs. Noyes.....	1,318.33	66.81
Pell, Cornelia Livingston, for maintenance of Alfred Duane Pell collection.....	10,171.36	515.48
Petrocelli, Joseph, for the care of the Petrocelli collection of photographic prints and for the enlargement and development of the section of photography of the U.S. National Museum.....	10,172.28	346.62
Rathbun, Richard, for use of division of U.S. National Museum containing Crustacea.....	14,594.68	739.66
*Reid, Addison T., for founding chair in biology, in memory of Asher Tunis..	24,468.96	1,237.04
Roebbling Collection, for care, improvement, and increase of Roebbling collection of minerals.....	165,608.24	8,393.11
Roebbling Solar Research.....	31,633.91	1,982.79
Rollins, Miriam and William, for investigations in physics and chemistry...	180,655.59	8,929.44
Smithsonian employees' retirement.....	33,368.40	1,722.74
Springer, Frank, for care and increase of the Springer collection and library..	24,607.44	1,247.14
Strong, Julia D., for benefit of the National Collection of Fine Arts.....	13,719.89	695.31
Walcott, Charles D. and Mary Vaux, for development of geological and paleontological studies and publishing results of same.....	657,407.55	33,444.26
Walcott, Mary Vaux, for publications in botany.....	79,429.98	4,025.53
Younger, Helen Walcott, held in trust.....	97,121.02	4,692.96
Zerbee, Frances Brincklê, for endowment of aquaria.....	1,301.61	65.98
Total.....	\$2,183,725.03	\$110,428.83

*In addition to funds deposited in the United States Treasury.

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for construction of a building to house the collection, and

finally in his will, probated November 6, 1919, he provided stocks and securities to the estimated value of \$1,958,591.42, as an endowment fund for the operation of the Gallery. The fund now amounts to \$8,902,456.42.

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes-----	\$2,294,725.03
Invested endowment for specific purposes other than Freer endowment-----	2,363,911.75
Total invested endowment other than Freer-----	4,658,636.78
Freer invested endowment for specific purposes-----	8,902,456.42
Total invested endowment for all purposes-----	13,561,093.20

CLASSIFICATION OF INVESTMENTS

Deposited in the U.S. Treasury at 6 percent per annum, as authorized in the U.S. Revised Statutes, sec. 5591-----	\$1,000,000.00
Investments other than Freer endowment (cost or market value at date acquired):	
Bonds-----	\$1,498,643.09
Stocks-----	2,142,849.59
Real estate and mortgages-----	5,753.00
Uninvested capital-----	11,388.10
Total investments other than Freer endowment-----	3,658,636.78
Investments of Freer endowment (cost or market value at date acquired):	
Bonds-----	\$5,258,223.18
Stocks-----	3,642,181.72
Uninvested capital-----	2,051.52
Total investments-----	8,902,456.42
Total investments-----	13,561,093.20

ASSETS

Cash:	
United States Treasury current account-----	\$1,317,923.50
In banks and on hand-----	313,938.41
	1,631,861.91
Less uninvested endowment funds-----	13,439.62
	\$1,618,422.29
Travel and other advances-----	4,426.77
Cash invested (U.S. Treasury notes)-----	1,328,578.18
	\$2,951,727.24

ASSETS—Continued

Investments—at book value:

Endowment funds:

Freer Gallery of Art:

Stocks and bonds-----	\$8,900,404.90	
Uninvested cash-----	2,051.52	
		\$8,902,456.42

Investments at book value other than Freer:

Stocks and bonds (Consolidated Fund)-----	3,543,261.44	
Uninvested cash-----	11,388.10	
Special deposit in U.S. Treasury at 6 percent interest -----	1,000,000.00	
Other stocks and bonds--	98,231.24	
Real estate and mortgages-----	5,756.00	
		4,658,636.78
		\$13,561,093.20
		<u>16,512,820.44</u>

UNEXPENDED FUNDS AND ENDOWMENTS

Unexpended funds:

Income from Freer Gallery of Art endowment-----	\$568,658.87
Income from other endowments:	
Restricted -----	\$442,629.88
General -----	467,271.34
	909,901.22

Gifts and contributions-----	1,473,167.15
	<u>2,951,727.24</u>

Endowment funds:

Freer Gallery of Art-----	\$8,902,456.42	
Other:		
Restricted -----	2,294,725.03	
General -----	2,363,911.75	
		13,561,093.20
Total-----		<u>16,512,820.44</u>

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL YEAR 1959¹

	Restricted funds		Unrestricted funds	Gifts and grants	Total
	General	Freer			
RECEIPTS:					
Income from investments:					
Freer fund.....		\$358,886.44			\$388,886.44
Consolidated fund.....	\$96,817.32		\$74,677.90		171,495.22
Loan to U.S. Treasury.....	6,660.00		53,810.00		60,000.00
Real estate and mortgages.....	326.78				326.78
Special funds—stocks and bonds.....	4,950.96		34,434.37		39,385.33
Total income from investments.....	108,755.06	388,886.44	162,452.27		660,093.77
Publications.....	2,002.13	10,887.09	75,376.24	\$912.70	89,178.16
Research grant income.....			46,883.33		46,883.38
Special gifts and fees:					
Gifts and contributions.....	10,120.00	5,000.00	222.05		15,342.05
Special service fees.....	174.71	101.04	14,413.55	105,180.29	119,869.59
Refund of advances.....			6,318.00		6,318.00
Employees' withholdings (net).....			594.18		594.18
Total special gifts and fees.....	10,294.71	5,101.04	21,547.78	105,180.29	142,123.82
Reinvestment (required by provision of donor).....	7,955.07		2,185.47		10,140.54
Gifts and grants ²				2,668,368.36	2,668,368.36
Total income.....	129,006.97	404,874.57	308,445.14	2,774,461.35	3,616,788.03
Sales of securities:					
Endowment funds:					
Freer fund.....		2,217,664.19			2,217,664.19
Consolidated fund.....	321,900.75		175,627.45		497,528.20
Other stocks and bonds.....	25,822.26				25,822.26
Total endowment funds sales.....	347,723.01	2,217,664.19	175,627.45		2,741,014.65
Investment of current funds in U.S. Government bonds.....			190,000.00		190,000.00
Total receipts.....	476,729.98	2,622,538.76	674,072.59	2,774,461.35	6,547,802.68
DISBURSEMENTS:					
Administrative salaries.....		34,360.45	87,843.80		122,204.25
Other salaries.....	7,812.66	133,888.80			141,701.46
Total salaries.....	7,812.66	168,249.25	87,843.80		263,905.71
Purchases for collection.....	28,322.76	220,268.00	1,439.50		250,030.26
Research and explorations and related administrative expense:					
Salaries ³			32,426.58	1,042,473.72	1,074,900.30
Travel.....	1,762.81	4,019.29	2,992.22		8,774.32
Equipment and supply.....	416.27		8,387.37		8,803.64
Other ³	2,295.15		8,513.11	1,252,423.78	1,263,232.04
Total research and explorations and related administrative expense.....	4,474.23	4,019.29	52,319.28	2,294,897.50	2,355,710.30
Publications.....	7,774.93	5,505.47	74,969.17		88,249.57

¹ This statement does not include Government appropriations under administrative charge of the Institution.² Includes receipts for IGY program.³ Includes disbursements for IGY program.

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING FISCAL YEAR 1959—Continued

	Restricted funds		Unrestricted funds	Gifts and grants	Total
	General	Freer			
DISBURSEMENTS—Continued					
Buildings, equipment, and grounds					
Buildings and installations		\$10,038.53	\$1,079.80		\$11,138.33
Court and grounds maintenance		306.54			306.54
Technical laboratory		385.28			385.28
Total buildings, equipment, and grounds		10,750.35	1,079.80		11,830.15
Contractual services:					
Custodian and legal fees	\$5,649.84	11,852.36	4,301.05		21,803.25
Supplies and expenses:					
Meetings, special exhibits		8,529.48	6,018.12		14,547.60
Lectures	430.12	1,128.10			1,558.22
Photographs and reproductions		5,271.12	415.05		5,686.17
Library		2,847.31	1,111.02		3,958.33
Stationery and office supplies			175.17		175.17
Postage, telephone, and telegraph			467.00		467.00
Stamp machines			1,831.00		1,831.00
Total supplies and expenses	430.12	17,776.01	10,017.36		28,223.49
Total expenses	54,464.54	438,420.73	231,969.96	\$2,294,897.50	3,019,752.73
Purchases of securities:					
Endowment funds:					
Freer fund		2,231,471.33			2,231,471.33
Consolidated fund	342,455.07		186,841.79		529,296.86
Other stocks and bonds	25,608.39				25,608.39
Total endowment funds	368,063.46	2,231,471.33	186,841.79		2,786,376.58
Investment of current funds in U.S. Government bonds			189,986.70		189,986.70
Total disbursements	422,528.00	2,669,892.06	608,798.45	2,294,897.50	5,996,116.01
Excess receipts over disbursements	54,201.98	(47,353.30)	65,274.14	479,563.85	551,686.67
Cash balance June 30, 1958					1,080,175.24
Cash balance June 30, 1959					1,631,861.91

The practice of maintaining savings accounts in several of the Washington banks and trust companies has been continued during the past year, and interest on these deposits amounted to \$7,501.11.

Deposits are made in banks for convenience in collection of checks, and later such funds are withdrawn and deposited in the United States Treasury. Disbursement of funds is made by check signed by the Secretary of the Institution and drawn on the United States Treasury.

The Institution gratefully acknowledges gifts and grants from the following:

American Council of Learned Societies, gift to defray travel expenses of Dr. Ralph Solecki to visit Paris to assist in the preparation of an international manual on salvage archeology.

American Institute of Biological Sciences, gift to defray travel expenses of Dr. Ernest A. Lachner.

Atomic Energy Commission, additional grants for the purpose of conducting a biochemical investigation of photomorphogenesis in green plants.

Anonymous donor, gift to establish the "Special Astrophysical Observatory Fund."

Anonymous donor, gift for the repair and maintenance of a coach.

Bredin, Mr. and Mrs. J. Bruce, additional gift for the Smithsonian-Bredin Expeditions Fund.

Carter Oil Company, additional grant for a research project on echinoid spines.

Chase, Mrs. Agnes, additional gift for copying the index to grass names.

Department of the Air Force, additional grants for research entitled "Study of Atmospheric Entry and Impact of High Velocity Meteorites."

Department of the Air Force, additional grants for research directed toward the study of the rate of accretion of interplanetary matter by the earth.

Department of the Army, grants for research entitled "Procurement of Satellite Tracking and Orbit Determination Program."

Fénykövi, J. J., gift for the unrestricted use of the Smithsonian Institution.

Hart, Gustavus E., bequest for the diffusion of useful knowledge among men and especially for the prevention of disease in human beings.

Henderson, E. P., gift to establish the "Meteorite Fund."

Kevorkian, H., grant to the Freer Gallery of Art.

Link, E. A., additional gift for historical research (marine archeology).

Link Foundation, gift to be used for special publications dealing with aviation and the Smithsonian Institution collections.

Likens, W. H., gift for the Smithsonian Institution's unrestricted funds.

Fred Maytag Family Foundation, gift for historical research (marine archeology).

National Geographic Society, additional grant to complete the excavations and related work at the archeological site in Jackson County, Alabama.

National Geographic Society, grant for an expedition to British Guiana for the purpose of collecting live specimens of the hoatzin and other birds and mammals.

National Science Foundation, additional grant for the support of research entitled "Studies of Type Specimen of Ferns."

National Science Foundation, additional grant for the support of research entitled "Monographic Studies of Tingidae and Presmidae (Hemiptera)."

National Science Foundation, grant for the support of research entitled "Systematic Studies of South American Microlepidoptera."

National Science Foundation, grant for the support of research entitled "Aboriginal History of the Peruvian Coast."

National Science Foundation, additional grant for the support of research entitled "Monograph of Fresh Water Calanoid Copepods."

National Science Foundation and National Aeronautics and Space Administration, grants for an optical tracking and scientific analysis program for the United States earth satellite program.

National Science Foundation, additional grant for the support of research entitled "Morphology and Paleocology of Permian Brachiopods."

National Science Foundation, grant for the support of research entitled "Taxonomic Study of the Phanerogams of Colombia."

National Science Foundation, grant for the support of research entitled "Data Reduction-Earth Albedo Observations During the International Geophysical Year Meteorology Program."

National Science Foundation, grant for the support of research on the metabolic aspects of the digestion of wax.

National Science Foundation, grant for the support of research entitled "Seminole Culture."

National Science Foundation, grant for the support of research entitled "Prehistoric Man in Shanidar Valley."

National Science Foundation, additional grant for the support of research entitled "Taxonomy of the Bamboos."

Office of Naval Research, additional grants to perform psychological research studies.

Office of Naval Research, additional grant to perform aeronautical research studies.

Office of Naval Research, additional grants to provide expert consultants to advise the Navy Research Advisory Committee.

Office of Naval Research, additional grant to assist work in progress on the preparation of a synoptic catalog of the mosquitoes of the world.

Office of Naval Research, grants to conduct studies of helminth parasites of Egypt and other Middle Eastern areas.

Petrocelli, Mrs. Mary O., bequest to establish the "Joseph Petrocelli Memorial Fund."

Research Corporation, grant for the support of research entitled "Spectrophotometric Investigation of the Photomorphogenic Pigment System."

Rocca, B. T., gift for the unrestricted use of the Smithsonian Institution.

Snyderman, I., gift to establish the "Numismatic Fund."

St. Petersburg Shell Club, gift to defray expenses of Dr. Harald Rehder in connection with travel to St. Petersburg.

United States Department of Agriculture, grant for the preparation of a catalog of mosquitoes.

University of the State of New York, gift to defray travel expenses of Dr. Herbert Friedmann while attending the conference on Systematic Museums as Resources for Basic Research.

Wenner-Gren Foundation, grant to aid participation in celebration of Hrdlička 90th Anniversary, Prague, 1959.

For support of the Bio-Sciences Information Exchange:

Atomic Energy Commission.

Department of the Air Force.

Department of the Army.

Department of the Navy.

National Science Foundation.

Public Health Service.

Veterans Administration.

Included in the above list of gifts and contributions are reimbursable contracts.

The foregoing report relates only to the private funds of the Institution.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1959:

Salaries and Expenses.....	\$7, 587, 800. 00
National Zoological Park.....	953, 800. 00

The appropriation made to the National Gallery of Art (which is a bureau of the Smithsonian Institution) was \$1,790,100.00.

In addition, funds were transferred from other Government agencies for expenditure under the direction of the Smithsonian Institution as follows:

Working Funds, transferred from the National Park Service, Interior Department, for archeological investigations in river basins throughout the United States.....	\$162, 000. 00
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The Institution also administers a trust fund for partial support of the Canal Zone Biological Area, located on Barro Colorado Island in the Canal Zone.

AUDIT

The report of the audit of the Smithsonian Private Funds follows:

WASHINGTON, D. C., *September 28, 1959.*

THE BOARD OF REGENTS,

SMITHSONIAN INSTITUTION, *Washington 25, D.C.*

We have examined the statement of private funds of Smithsonian Institution as of June 30, 1959 and the related statement of private funds cash receipts and disbursements for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Land, buildings, furniture, equipment, works of art, living and other specimens and certain sundry property are not included in the accounts of the Institution; likewise, the accompanying statements do not include the National Gallery of Art and other departments, bureaus, and operations administered by the Institution under Federal appropriations. The accounts of the Institution are maintained on the basis of cash receipts and disbursements, with the result that the accompanying statements do not reflect income earned but not collected or expenses incurred but not paid.

In our opinion, subject to the matters referred to in the preceding paragraph, the accompanying statement of private funds presents fairly the assets, unexpended funds and endowments of the private funds of Smithsonian Institution at June 30, 1959; further, the accompanying statement of private funds cash receipts and disbursements, which has been prepared on a basis consistent with that of the preceding year, presents fairly the cash transactions of the private funds for the year then ended.

PEAT, MARWICK, MITCHELL & Co.

Respectfully submitted.

/s/ ROBERT V. FLEMING

/s/ CLARENCE CANNON

/s/ CARYL P. HASKINS

Executive Committee.

GENERAL APPENDIX
to the
SMITHSONIAN REPORT FOR 1959

ADVERTISEMENT

The object of the **GENERAL APPENDIX** to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by staff members and collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report of 1889, a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1959.

Reprints of the various papers in the General Appendix may be obtained, as long as the supply lasts, on request addressed to the Editorial and Publications Division, Smithsonian Institution, Washington 25, D.C.

The Transuranium Elements¹

By GLENN T. SEABORG

*Chancellor, University of California
Berkeley*

[With 1 plate]

THE STUDY of the transuranium elements is an exciting branch of science, which started less than 20 years ago and has a clearly discernible future of great expansion. These elements represent the realization of the alchemists' dream of transmutation. They have played an important role in the recent renaissance of inorganic chemistry. An advance as fundamental as a 10-percent increase in the number of chemical elements has, as one might anticipate, contributed much to our fund of the most basic scientific knowledge, especially in the fields of chemistry and physics.

The chemistry and physics of the longer known transuranium elements are already remarkably developed, and extremely interesting. Neptunium has an isotope sufficiently long lived to be safe to handle with moderate precautions in ordinary laboratories; plutonium and curium have similarly long-lived isotopes which should eventually make these elements available for broader investigation throughout the world when they become more available. One of the transuranium elements, plutonium, is particularly interesting. It has an isotope with nuclear properties such that it is destined to play an extremely important role in the history of mankind. Plutonium was discovered and methods for its manufacture were worked out under the cloak of secrecy during the last war. It was the first synthetic element to be seen by man and the first example of large-scale production of an element by transmutation. Plutonium has most unusual chemical and metallurgical properties. For example, it has four oxidation states which may exist in aqueous solution in equilibrium with each other at appreciable concentrations. The metallic form has six allotropic modifications between room temperature and its melting point, some with properties unknown in any other metal. The alpha-radioactivity and physiological behavior of its fissionable iso-

¹ Reprinted by permission from *Endeavour*, vol. 18, No. 69, January 1959.

tope, Pu^{239} , makes this one of the most dangerous known poisons. The announcement of its discovery to the world was through the atomic bomb that fell on Nagasaki. Plutonium, of course, has an important future in nuclear power. The fissionable isotope Pu^{239} makes its source isotope U^{238} , which is not fissionable with slow neutrons, a potential nuclear fuel. The fertile U^{238} is "burned" by going through the intermediate fissionable Pu^{239} .

The discovery of the first transuranium element followed a false start 6 years earlier. When Enrico Fermi and his coworkers first bombarded uranium with slow neutrons in 1934 they found that a number of artificially radioactive species were produced, and in the immediately following years many more such substances were observed. Most of these were thought to be transuranium elements. Chemical investigation, however, led to the discovery of the fission process rather than to the discovery of transuranium elements. Subsequent work has shown that practically all the radioactive species believed to be transuranium elements were in fact fission products of uranium. In 1940 E. M. McMillan and P. H. Abelson discovered the first transuranium element. This was neptunium, with atomic number 93. In the following years, many more transuranium elements—plutonium (94), americium (95), curium (96), berkelium (97), californium (98), einsteinium (99), fermium (100), mendelevium (101), and element 102—were synthesized and identified. The elements up to and including einsteinium have isotopes sufficiently long lived to be isolated in macroscopic, that is weighable, quantities, but this does not seem to be true beyond einsteinium.

The transuranium elements are, for all practical purposes, synthetic in origin and must be produced by transmutation, starting, in the first instance, with uranium. However, two of them, neptunium and plutonium, are present in trace concentrations in uranium ores as the result of the action of the neutrons which are present. Investigation of these new elements has resulted in the contribution of much information to inorganic chemistry, since they have a rich and varied chemical behavior, form unusual compounds, and in some cases display an extraordinary complexity in solution. The relationship of these elements to each other and to the other elements is now within our understanding. Problems inherent in the study of these elements, such as those of handling quantities of material so small as to be unweighable, of working in safety with radioactive materials, and of preparing and identifying elements of ever-increasing atomic number, are being solved.

POSITION IN THE PERIODIC TABLE

Ideas on the position in the periodic table (table 1) of the heaviest elements have varied considerably over the years. Until the last war,

1 H 1.0080																	2 He 4.003		
3 Li 6.940	4 Be 9.013																		
11 Na 22.991	12 Mg 24.32	5 B 10.82	6 C 12.011	7 N 14.008	8 O 16.000	9 F 19.00	10 Ne 20.183												
19 K 39.100	20 Ca 40.08	13 Al 26.98	14 Si 28.09	15 P 30.975	16 S 32.066	17 Cl 35.457	18 Ar 39.944												
37 Rb 85.48	38 Sr 87.63	21 Sc 44.96	22 Ti 47.90	23 V 50.95	24 Cr 52.01	25 Mn 54.94	26 Fe 55.85	27 Co 58.94	28 Ni 58.71	29 Cu 63.54	30 Zn 65.38	31 Ga 69.72	32 Ge 72.60	33 As 74.91	34 Se 78.96	35 Br 79.916	36 Kr 83.80		
55 Cs 132.91	56 Ba 137.36	39 Y 88.92	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc 101.1	44 Ru 101.1	45 Rh 102.91	46 Pd 106.4	47 Ag 107.880	48 Cd 112.41	49 In 114.82	50 Sn 118.70	51 Sb 121.76	52 Te 127.61	53 I 126.91	54 Xe 131.30		
87 Fr	88 Ra	57-71 La Series	72 Hf 178.50	73 Ta 180.95	74 W 183.86	75 Re 186.22	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 197.0	80 Hg 200.61	81 Tl 204.39	82 Pb 207.21	83 Bi 208.99	84 Po	85 At	86 Rn		
		89-103 Ac Series	(104)	(105)	(106)	(107)	(108)												

Lanthanide Series	57 La 138.92	58 Ce 140.13	59 Pr 140.92	60 Nd 144.27	61 Pm	62 Sm 150.35	63 Eu 152.0	64 Gd 157.26	65 Tb 158.93	66 Dy 162.51	67 Ho 164.94	68 Er 167.27	69 Tm 168.94	70 Yb 173.04	71 Lu 174.99
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Actinide Series	89 Ac 227.04	90 Th 232.05	91 Pa 231.05	92 U 238.04	93 Np 237.06	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 E	100 Fm	101 Mv	102	(103)
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TABLE I.—Periodic table of the elements.

thorium, protoactinium, and uranium were commonly placed immediately below the elements hafnium, tantalum, and tungsten, which are members of a transition series in which the 5d electron shell is being filled. This placing was based on the assumption that the three heavy elements were members of a 6d electron transition series. The appearance of N. Bohr's paper on the quantized nuclear atom in 1913 led to suggestions that a 5f electron transition series should start in the region thorium to element 93 inclusive, before the completion of the 6d electron shell. With the discovery of neptunium and then plutonium, the boundaries of the periodic table were transcended, and as knowledge of the first transuranium elements accumulated, it became evident that a whole new family of elements, some known and some still to be discovered, existed in this region of the periodic table.

The fact that the transuranium elements are members of a transition series similar to the rare earth, or lanthanide, series is useful in predicting the chemical properties of these elements before they are actually detected. This particular pattern of similarity, recognized by the author in 1944 on the basis of the chemical properties of neptunium and plutonium, was the key to the discovery of elements 95 and 96 (americium and curium) and has been essential to the discovery of the transcurium elements. Since all the elements beyond actinium seem to belong to the actinide group (a name chosen by analogy with the lanthanide group), the elements thorium, protoactinium, and uranium have been removed from the positions they occupied in the periodic table before 1939 and placed in this transition family; as we shall see, elements 104, 105, and 106 will presumably take over the positions previously held by thorium, protoactinium, and uranium. Thus we have the interesting result that the newcomers have affected the face of the periodic table, and a change has been made after many years during which it seemed to have assumed its final form.

NEPTUNIUM

The discovery of the first transuranium element, neptunium, resulted from McMillan's investigation of the fission process. In measuring the energies of the two main fragments from the neutron-induced fission of uranium, he found that there was another radioactive product of the reaction, one which did not recoil sufficiently to escape from the thin layer of uranium undergoing fission. He suspected that this was a product formed by neutron capture in the uranium. McMillan and Abelson were able to show on the basis of their chemical work that this product was an isotope of element 93 (Np^{239}), arising by beta decay of U^{239} formed by neutron capture in U^{238} .

It was not obvious what the electronic configuration and chemical properties of neptunium might be. Uranium was known to have

some similarity to tungsten, and it was thought that element 93 might resemble rhenium, the next element beyond tungsten. There was the possibility, however, that neptunium might be a member of some new type of transition series among the heavy elements. McMillan and Abelson's investigation of neptunium showed that it resembles uranium, not rhenium, in its chemical properties. This was the first definite evidence that the 5f electron shell is filled in the transuranium region.

The early investigation of neptunium, as of all the transuranium elements, was made by the tracer technique. In this method, an element having chemical properties similar to those of the element being studied is used to follow the behavior of the radioactive element, which is present in amounts as small as 10^{-10} g., or even less. The element is followed in the various reactions by means of its radioactivity rather than by chemical analysis. In spite of the smallness of the quantities present, much can be deduced about the chemical properties of an element—for example, the solubility of its compounds, its oxidation-reduction potentials, and its formation of complexions—by the use of such methods.

PLUTONIUM

Plutonium was next to be discovered. By bombarding uranium with deuterons, E. M. McMillan, J. W. Kennedy, A. C. Wahl, and the author, in late 1940, succeeded in preparing a new isotope of neptunium, Np^{238} , which decayed to Pu^{238} . The half-life of this isotope was found to be sufficiently long to permit detection and to make possible our obtaining considerable chemical information about it by tracer studies. Armed with this information about the new elements, J. W. Kennedy, E. Segrè, A. C. Wahl, and the author in 1941 identified the most important plutonium isotope, Pu^{239} , as the decay product of Np^{239} and we were able to prove that Pu^{239} undergoes fission with slow neutrons.

The realization that plutonium, as Pu^{239} , could serve as a nuclear weapon and that it might be created in quantity in a nuclear chain reactor made it imperative to carry out chemical investigations of plutonium with microgram quantities. In August 1942, B. B. Cunningham and L. B. Werner succeeded in isolating about a microgram of Pu^{239} which had been prepared by cyclotron irradiations. Thus plutonium was the first manmade element to be obtained in visible quantity.

A background of manipulative techniques for this ultramicrochemical work was provided by the pioneer investigations of P. L. Kirk and A. A. Benedetti-Pichler. If extremely small volumes are used, even microgram quantities of material can give relatively high con-

centrations in solution, and with the development of balances of the required sensitivity, micrograms were also sufficient for gravimetric analysis. Liquid volumes in the range 10^{-1} to 10^{-5} ml. were measured with an error of less than 1 percent by means of finely calibrated capillary tubing, the movement of liquid being controlled by air pressure. Smaller pipettes were constructed to fill by capillary action. Chemical glassware, such as test tubes and beakers, was constructed from capillary tubing having an internal diameter of 0.1–1 mm. and was handled with micromanipulators. The weights of solid reagents and precipitates handled in ultramicrochemical work are usually in the range of 0.1–100 μg . There are some changes in method involved in the change of scale—thus, solids are usually separated from liquids by centrifuging rather than by filtration. The actual chemical work is usually done on the mechanical stage of a microscope, where the essential apparatus is within view (fig. 2). Among the early accomplishments in ultramicrochemistry was the isolation of pure neptunium (pl. 1, fig. 1) and pure plutonium compounds (pl. 1, fig. 2) as well as the preparation of plutonium metal. Figures 1 and 3 show schematic drawings of the experimental arrangements used in the preparation of pure plutonium metal and pure plutonium trichloride.

Plutonium is the only synthetic element that has been produced and isolated in kilogram quantities. The large plant at Hanford, Wash., was constructed on the basis of investigations performed with about 2 mg. of plutonium; the scaleup between ultramicrochemical experiments to the final Hanford plant corresponds to a factor of about 10^9 , surely a scaleup of unique proportions.

Frequently chemical investigation of plutonium and of other transuranium elements is carried out on a scale of a milligram or less by choice, rather from any limitation on supply— Pu^{239} is exceedingly toxic because of its high alpha-radioactivity, amounting to about

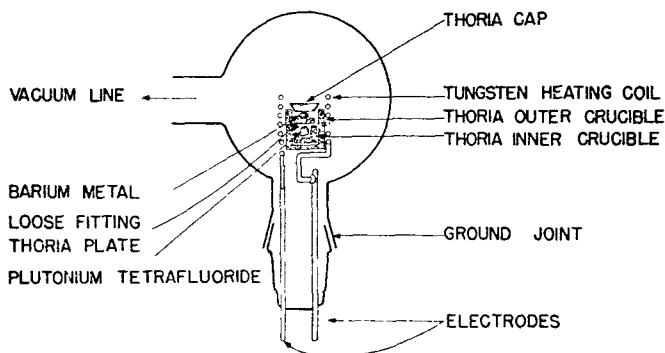


FIGURE 1.—Apparatus used in the first preparation of plutonium metal (November 1943). 35 μg of plutonium tetrafluoride was treated with volatilized barium metal in a thoria crucible at 1400°C . The metallic plutonium was produced as silvery globules weighing about 3 μg each.

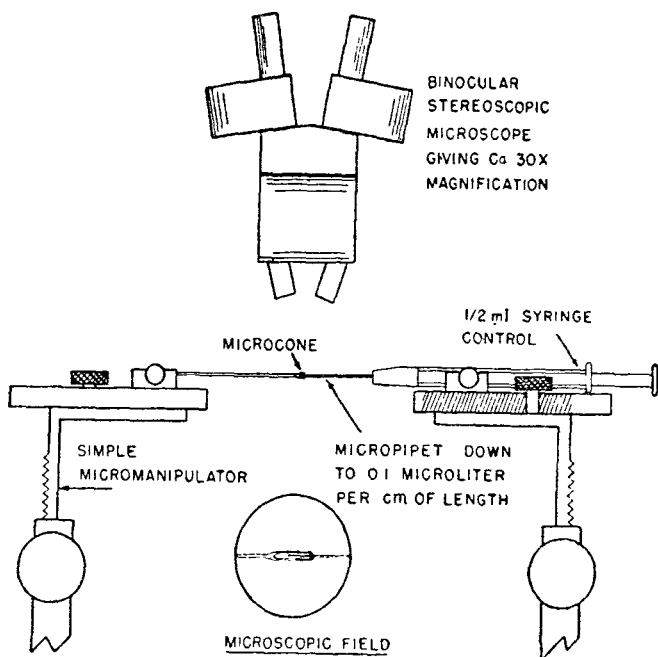


FIGURE 2.—Experimental arrangement for the study of precipitation reactions on the microgram scale.

140 million alpha-disintegrations per minute per milligram; special equipment and precautions, as well as the use of material in very small amounts, are necessary when working with it.

AMERICIUM AND CURIUM

After plutonium had been produced in quantity, the discoveries of americium (1944–45) and curium (1944) were made. The speed of discovery of these elements was due largely to the accurate prediction of their chemical properties on the basis of their assumed position in the periodic table (p. 249). Curium, discovered by R. A. James, L. O. Morgan, A. Ghiorso, and the author, was synthesized as Cm^{242} by the bombardment of plutonium with helium ions. The production of americium by James, Ghiorso, and the author was accomplished by preparing Pu^{241} , which decays by beta emission to Am^{241} .

IDENTIFICATION BY ION EXCHANGE

The ion-exchange technique, coupled with element-by-element comparison of the behavior of corresponding actinide and lanthanide elements, has been essential in the discovery of the transuranium elements. Since the actinide elements above plutonium are predominantly trivalent in solution and have a close chemical resemblance, most conventional chemical separations are not suitable. Again, the

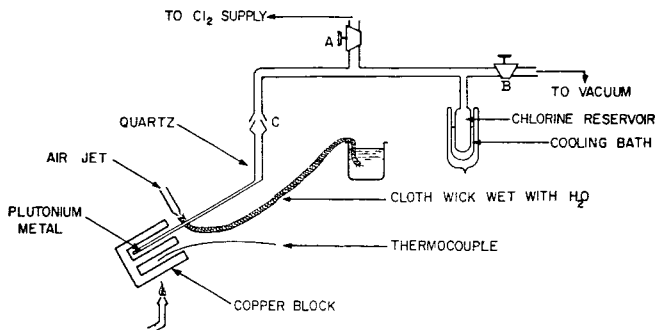


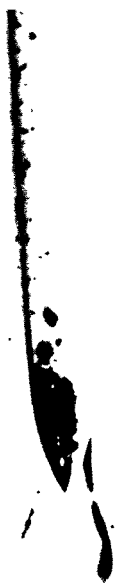
FIGURE 3.—Apparatus used in the first preparation of PuCl_3 (February 1944). The compound was prepared by treating a 50- μg piece of plutonium metal with chlorine gas. After placing the plutonium in the capillary tube, the system was evacuated. Chlorine gas was added, and a small amount condensed in a reservoir as shown. The system was closed and remained filled with chlorine at a pressure of about 60 mm. Hg. The copper block was heated to 45°C ., and the reaction product was formed in the top of the capillary tube. The section of the capillary containing the product was sealed off and the compound formed was identified by X-ray diffraction.

first isotopes of the new actinide elements were obtained in very small amounts, and are very short lived. Specific and rapid methods are therefore necessary in identifying these elements, and ion exchange provides both. Much of the chemical knowledge we have of the actinide elements heavier than curium is concerned with their ion-exchange and elution properties.

The trivalent actinide and lanthanide ions in aqueous solution undergo a cation exchange when a solid organic base-exchange polymer is stirred in. The solid material can then be placed at the top of a glass column filled with more of the organic polymer that is free of the actinides or lanthanides. Elution can then be accomplished by pouring through the column a solution containing ions that form complex ions with the actinide or lanthanide ions. In certain well-behaved systems the lanthanide elements elute from the column in the inverse order of their atomic numbers, that is, lutetium can be collected as the first element in the drops coming through the column, ytterbium as the second element, and so on to cerium. The whole process bears a close resemblance to chromatography. In the case of the actinides, the undiscovered element 103 will leave the column first, followed by element 102, and so on down the scale of atomic numbers.

BERKELIUM AND CALIFORNIUM

At the end of 1949 and beginning of 1950, experiments led to the production of elements 97 and 98, berkelium and californium. The first six transuranium elements were discovered almost in pairs, with time lapses corresponding to necessary improvements in technique and the accumulation of starting material. Milligram amounts of ameri-



1 First neptunium compound isolated. The neptunium, present as the oxide, appears at the bottom of the capillary tube. The sample was isolated in 1944 and weighed about 10 μ g.



2. First plutonium compound to be weighed (September 10, 1942). The plutonium, present as the oxide, appears as a crusty deposit, indicated by the arrow, near the end of a platinum weighing boat which is held by forceps. The weight of the plutonium oxide was 2.77 μ g. ($\times 20$.)



cium for target material were prepared by the intense neutron irradiation of plutonium for a long time; this process builds up the heavier elements by a series of neutron captures. Curium for target material was prepared in microgram amounts by the neutron irradiation of some of the americium. Both of these neutron bombardments were carried out in high-flux reactors. Berkelium, as the isotope Bk^{243} , was discovered by S. G. Thompson, A. Ghiorso, and the author in December 1949, as a result of the bombardment of americium with helium ions. Californium was first synthesized and identified by S. G. Thompson, K. Street, Jr., A. Ghiorso, and the author in February 1950, the isotope Cf^{245} being produced by the bombardment of microgram amounts of curium with helium ions. The identification of californium was accomplished with a total of about 5,000 atoms.

EINSTEINIUM AND FERMIUM

The first test thermonuclear explosion, which took place in the Pacific in November 1952, led to the discovery of elements 99 and 100, einsteinium and fermium. These two elements were found in debris, collected first on filter papers attached to aeroplanes which flew through the explosion area and later in more substantial quantities by gathering up surface materials from a neighboring atoll. The uranium in the fission-fusion device was subjected to an instantaneous intense neutron flux which gave rise to very heavy uranium isotopes. These rapidly decayed into heavy isotopes of plutonium, americium, curium, berkelium, californium, and elements 99 and 100. These reaction products were investigated by groups at the University of California Radiation Laboratory, Argonne National Laboratory, and Los Alamos Scientific Laboratory. The two elements were discovered by Ghiorso and coworkers at the three laboratories.

Einsteinium and fermium can be synthesized by a number of methods. Chief among these is the irradiation of plutonium for several years with an extremely high neutron flux in such a reactor as the Materials Testing Reactor at Arco, Idaho. The einsteinium used to produce element 101 was prepared in the Materials Testing Reactor.

MENDELEVIUM

The synthesis of element 101 was planned and accomplished not only with an amount of target einsteinium (E^{253}) so small as to be unweighable, but also with the expectation that no more than one atom of element 101 per experiment would be produced. Only about 1,000 million atoms of E^{253} were available for target material. In addition, the separation of the one atom of element 101 from the 10^9 atoms of target einsteinium and its ultimate complete chemical identification

by separation in the eka-thulium position by the ion-exchange method would have to be accomplished. These requirements necessitated new techniques, and also some luck; fortunately, both were forthcoming. The new technique involved the separation of element 101 from the einsteinium in the target by the recoil method. The einsteinium was plated onto a gold foil in an invisibly thin layer. The helium-ion beam was sent through the back of the foil so that the atoms of element 101, recoiling because of the momentum of the impinging helium ions, could be caught on a second thin gold foil. This second gold foil, containing recoil atoms, yet relatively free of the target einsteinium, was dissolved and the chemical separations were performed. Very sensitive methods were available for the detection of isotopes decaying by alpha-particle emission or by spontaneous fission. These methods were so efficient that as little as one or two atoms of element 101 per experiment could be detected.

The earliest experiments were confined to looking for short-lived alpha-emitting isotopes that might be due to element 101. However, no alpha activity was observed that could be attributed to element 101, even when the time between the end of the bombardment and the beginning of the alpha-particle analysis was reduced to 5 minutes.

The experiments were continued, and in one of the subsequent bombardments, a single large pulse due to spontaneous fission was observed. Chemical experiments indicated that the spontaneous fission counts, when they did appear, came in chemical fractions corresponding approximately to element 100 or 101. In the definitive experiments, three successive 3-hour bombardments were made, and, in turn, their transmutation products were completely and quickly separated by the ion-exchange method. A total of five spontaneous fission counts was observed in the elution position corresponding to element 101, while a total of eight spontaneous fission counts was also observed in the element 100 position. No such counts were observed in any other position. The spontaneous fission activity in both the element 101 and 100 fractions decayed with a half-life of about 3 hours. This and other evidence led to the view that the isotope has the mass number 256 and decays by electron capture, with a half-life of the order of an hour, to the isotope Fm^{256} which is responsible for the spontaneous fission decay.

On the basis of this evidence, the group, consisting of A. Ghiorso, B. G. Harvey, G. R. Choppin, S. G. Thompson, and the author, announced the discovery of element 101. We gave the new element the name mendelevium in recognition of the pioneering role of Dmitri Mendeleev, who was the first to use the periodic system of the elements to predict the chemical properties of undiscovered elements. Subsequent experiments using larger amounts of einsteinium in the target

have led to the production of over 100 atoms of mendelevium. The indications are that mendelevium is a typical tripositive actinide element and a true eka-thulium, as expected.

ELEMENT 102

The discovery of element 102 was announced in 1957 as the result of work done at the Nobel Institute for Physics in Stockholm by a team of scientists from the Argonne National Laboratory, the Atomic Energy Research Establishment at Harwell, and the Nobel Institute. An isotope of the element was reportedly produced by bombarding Cm^{244} with cyclotron-produced $\text{C}^{13(+4)}$ ions and decayed with a half-life of about 10 minutes by the emission of 8.5 MeV alpha particles. The name nobelium for element 102 was suggested by this group. Unfortunately it has not been possible to confirm this discovery in experiments performed at the University of California Radiation Laboratory. In April 1958 a group consisting of Ghiorso, T. Sikkeland, J. R. Walton, and the author at the Radiation Laboratory identified the isotope 102^{254} as a product of the bombardment of Cm^{246} with C^{12} ions accelerated in the new heavy-ion linear accelerator there. (The reaction is $\text{Cm}^{246}(\text{C}^{12}, 4n)102^{254}$). The element 102 isotope decays by alpha-particle emission with a half-life of about 3 seconds. It was detected by the chemical identification of its known daughter Fm^{250} , the atoms of the daughter element being separated from the parent element 102 by taking advantage of the recoil due to element 102 alpha-decay. Although the name nobelium for element 102 will undoubtedly have to be changed, the investigators have not, at the time of writing, made their suggestion for the new name.

COMPARISON OF ACTINIDES AND LANTHANIDES

The resemblance between the actinide and lanthanide elements suggests that their electronic structures must be similar. In the lanthanide elements, the 14 4f electrons are added one by one, beginning with cerium (atomic number 58) and ending with lutetium (atomic number 71). In the actinide elements, 14 5f electrons are added, beginning formally with thorium and ending with element 103. The evidence for this, which is too complex and lengthy to discuss in this article, lies in the chemical properties, absorption and fluorescence spectra in aqueous solution and crystals, crystallographic structure data, magnetic data, and spectroscopic data. The lanthanide gadolinium, with seven 4f electrons, and the actinide curium, with seven 5f electrons, are of especial interest because of the enhanced stability of the half-filled f-electron shell configuration. The two elements have been found to have properties that are strikingly similar. The family relationship within the actinide group means that the study of any one of

them often gives indirect information about the chemical properties of another. Thus certain anomalous elution sequences among the transplutonium elements have made it possible to make deductions about the chemical properties of plutonium in relation to its electronic structure.

There are important differences between the actinide and lanthanide elements, however, due largely to the lower binding energies and less effective shielding by outer electrons of 5f (as compared to 4f) electrons. It appears that the first 5f electron is not present in thorium. Evidence to date indicates that uranium possesses three 5f electrons. The additional 5f electrons apparently are added to the succeeding elements in a regular fashion, proceeding through curium with its half-filled shell to the as yet undiscovered element 103 which presumably will have 14 5f electrons. In the early members of the actinide group particularly, the lower binding energies of the 5f electrons compared to the 4f electrons tend to make higher oxidation states more accessible. For these lighter actinide elements, the problem of assignment of electrons to 5f or 6d orbitals is difficult, since here the energy separations apparently lie within the range of chemical binding energies. It may not be possible to establish from the configuration of the gaseous atom the electronic structure of the compounds or of hydrated ions in aqueous solution. In the case of the lanthanide elements, the configuration of the gaseous atom includes, in general, only two electrons (beyond the xenon structure) outside the 4f shell, although the predominant oxidation state in aqueous solution is the trivalent state. It may also be noted that for a given element in the actinide group there is a stabilization of 5f compared to 6d electrons with increasing oxidation state.

However, the differences between the actinide and lanthanide groups give opportunities for the investigation of important new chemical phenomena. For example, their energetic position and larger spatial extension make the 5f orbitals available in bond hybridization; this leads to some very interesting complex ions. Similarly, the exposure of the 5f electrons can lead to field-splitting effects which can affect ionic entropies in manners which have not been observed in the lighter elements.

FUTURE DEVELOPMENTS

The discovery of further new transuranium elements seems possible. Studies of the known isotopes of the transuranium elements have made possible the prediction of the decay properties of new isotopes. For decay by both alpha-particle emission and spontaneous fission, the regularities have been found to be greatest for nuclei which contain an even number of neutrons and an even number of protons, thus

making predictions of the properties for undiscovered isotopes of this type more certain. The rates of decay by alpha-particle emission and by spontaneous fission are slower for isotopes having an odd number of protons or an odd number of neutrons or an odd number of both protons and neutrons. Unfortunately for the prospect of producing ever higher elements, the predictions suggest shorter half-lives as atomic number increases. By the time elements 104 and 105 are reached, we shall probably find that the longest-lived isotopes that can be made will exist barely long enough for chemical identification. In the case of element 104, the predicted half-lives of the longest-lived isotopes are measured in seconds or minutes and for element 105 in seconds. It should be mentioned, however, that any of these nuclides can have a specially hindered decay, leading to longer half-lives than those predicted. It is likely that the present basic criterion for the discovery of a new element, namely chemical identification and separation from all previously known elements, will have to be changed at some point. Careful measurements of decay properties and production yields and mechanisms, and the clever use of recoil techniques, should eventually allow the extension of effective identification to another half-dozen elements or so beyond the heaviest now known. In fact the identification of the first isotopes of all the new elements that will be discovered in the future probably will be accomplished through the use of such methods, and the production of isotopes with sufficiently long half-lives to allow chemical identification will follow later. For the isotopes with very short half-lives, some chemical identification can probably be made using simpler and faster methods involving migration, volatility, reactions with surfaces, or gas-flow reactions.

Some interesting predictions concerning superheavy nuclei have been made. J. A. Wheeler has been able to show that extranuclear electrons for atoms with atomic number substantially higher than 137 (often considered the upper limit) would behave normally because of the finite extension of the nucleus. Accordingly it would appear that there is no limitation on the existence of such heavy elements from the standpoint of the electronic structure of such atoms. The production of such nuclei would require extremely high neutron fluxes, of the order of 10^{31} neutrons per square centimeter per second, such as may be present in stars. It is difficult to see how such nuclei can be made on earth. There is no indication that such superheavy nuclei can be produced and detected, because the rate of decay increases rapidly as the atomic number increases. Unless unexpected islands of stability due to closed neutron or proton shells are found, predictions based on regularities in decay properties suggest that it should not be possible to produce and detect elements beyond another half dozen or so.

The prediction of the chemical properties of elements beyond mendelevium seems to be quite straightforward. Element 103 should complete the actinide series, and it is expected that elements 104, 105, 106, etc., will be fitted into the periodic table under hafnium, tantalum, tungsten, etc. The filling of the 6d electronic shell should be followed by the addition of electrons to the 7p shell, with the attainment of the rare gas structure at hypothetical element 118. It seems quite certain that the chemical identification of elements 102 and 103 will eventually be made by ion exchange, using knowledge of their homologs ytterbium and lutetium and other actinide elements. Element 102 might be expected to have a stable trivalent oxidation state and a somewhat unstable bivalent state which may be of importance in the chemical identification of the element. The bivalent state of element 102, if it is comparable in stability to the bivalent state of ytterbium, may permit a rapid separation of element 102 from the other actinide elements by electrolytic or amalgam reduction using ytterbium as a carrier. The stability of the bivalent state may be reflected in the properties of the metallic state of the element, resulting in an unusually low density and a relatively high volatility. Element 103 might be expected to have only a trivalent oxidation state. Element 104 should be exclusively tetravalent in aqueous solution and should resemble its homolog hafnium. Element 105 should resemble niobium and tantalum, and to some extent protoactinium, with the pentavalent oxidation state expected to be the most important. The chemical properties of element 106 can be predicted from those of tungsten, molybdenum, and to some extent chromium; thus we might expect to find the III, IV, V, and VI oxidation states. Elements 107, 108, 109, 110, etc., would be expected to have chemical resemblance to rhenium, osmium, iridium, and platinum respectively.

The possibility of preparing transfermium elements by the process of multiple neutron capture as a result of intense neutron bombardment over long periods of time is almost precluded by the fact that some of the intermediate isotopes have half-lives so short as to prohibit their presence in such appreciable concentrations as are required. Fortunately, there is another type of nuclear reaction that offers promise for the production of elements of higher atomic number than those now known. This is the method of bombardment with heavy ions. Reactions of this type have already been observed in many laboratories; isotopes of californium, einsteinium, and fermium have been produced by the bombardment of uranium with carbon ions, nitrogen ions, and oxygen ions, respectively. These ions can be accelerated in conventional cyclotrons. A linear accelerator capable of producing substantial beams of all the heavy ions up to neon and, possibly, usable beams of ions as heavy as those of argon has been constructed

at the University of California at Berkeley. A similar accelerator is in operation at Yale University. Russia has shown a great interest in heavy ions and their application to the synthesis of transuranium elements and has accelerators for heavy ions under construction. Even with use of heavy ions, however, the source of target materials will present serious problems. New, expensive, high-flux reactors, producing 10^{15} to 10^{16} neutrons per square centimeter per second, are needed in order to prepare even milligram amounts of berkelium, californium, and einsteinium within a reasonable space of time.

This short article has, of necessity, omitted even reference to many of the important aspects of the transuranium element field. In particular, it has not been possible to capture the international flavor of the work which has gone on in recent years. The emphasis has been on the chemical properties, the historical aspects, and the possibilities for future advances in this field. Much of interest could be told of the methods of production and of the many new long-lived isotopes which are becoming available in weighable amounts. The nuclear properties, which were barely mentioned, are of great interest. Over 80 isotopes of the transuranium elements are now known. The decay properties of these have been of great importance for the development of the Copenhagen school's unified model of the nucleus, and the induced and spontaneous fission properties of such isotopes are very important to the future development of a satisfactory theory for the nuclear-fission process.

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The IGY in Retrospect

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[With 3 plates]

ON DECEMBER 31, 1958, there was concluded a worldwide intellectual effort often characterized as the greatest cooperative enterprise for peaceful purposes in all human history. Between 20,000 and 30,000 scientists of 67 nations, with innumerable supporting workers, endeavored to expand man's understanding of his physical environment. This was the International Geophysical Year.

It is truly remarkable that such an enterprise was successfully planned and executed, in a period of unprecedented political passions and tension, through direct contact between scientists themselves without recourse to diplomatic intervention or formal treaties. As a result we have new and powerful ties on an individual level between leading scientists of many lands, mounting understanding for one another, a great breach in the Iron Curtain, and a demonstration that men of many races and political faiths can work together fruitfully. Even if these accomplishments cannot be exactly evaluated, their meaning for the world is deep and pervasive.

A number of great discoveries were made and more will inevitably grow out of the gradual assimilation, in years to come, of the accumulated data of the IGY. The borders of our knowledge of man's environment were pushed back in several important respects, with an already vast and growing store of new knowledge which will sharply influence the course of human development.

The space age was inaugurated under the auspices of the IGY: study and exploitation of our last geographical frontiers in Antarctica and over the oceans began to flourish in a new spirit of international cooperation; the age-old concern of all mankind with weather received tremendous new impetus; and human beings took bold steps toward better understanding of the earth itself, its physical structure and its gravitational and magnetic fields; of its earthquakes, orogenic processes and glaciation; of the chemical and physical processes

of its oceans and atmosphere; and of its all-important relations to our sun.

One of the great physical-science discoveries of all time was made by a member of the small group of geophysicists who were the actual creators of the IGY. It was at an informal meeting at the Silver Spring, Md., home of James A. Van Allen that this group met on April 3, 1950, to discuss geophysical matters with a renowned visiting British upper atmosphere scientist, Sidney Chapman. Among those present was Lloyd V. Berkner, a foremost American scientist, then of the Carnegie Institution of Washington, who there proposed a successor to two previous international efforts known as International Polar Years. This was the genesis of the IGY—an undertaking destined to bring Dr. Van Allen to fame as discoverer of the great Van Allen radiation belts in space surrounding the earth. The implications of his discovery are as yet unimaginable, but they are certainly tremendous—quite possibly comparable with those attending the discovery of radio waves.

THE FIRST AND SECOND INTERNATIONAL POLAR YEARS

The first and second polar years were, in a sense, models for the IGY. The famous American naval officer M. F. Maury had suggested international scientific exploration of Antarctica as early as 1861, but his rather limited proposals did not meet with acceptance. Karl Weyprecht, an Austrian explorer-scientist, who had interested himself in the then-inexplicable vagaries of weather, the compass, and auroral displays experienced by 19th-century Arctic explorers, later proposed an international effort to acquire simultaneously data from a circumpolar chain of stations. There resulted in 1882–83 a so-called International Polar Expedition, under what was later known as the International Meteorological Organization. The agreed term of occupation was a 13-month interval known as the International Polar Year beginning August 1, 1882. It happened that solar activity at the time was near a peak of the 11.2-year recurrence cycle.

Twelve countries rallied to Weyprecht's call, establishing 12 stations in the Arctic and 2 in sub-Antarctica. Weyprecht did not live to see the realization of his idea; however, the scientific world received an important new mass of data, a heightened awareness of complex relationships between several of the manifestations under observation, and the stimulus of working together without regard to political or racial barriers.

The Second International Polar Year followed a 1927 proposal by J. Giorgi of Hamburg. It was carried on by a special commission of the International Meteorological Organization, with D. LaCour of the Danish Meteorological Institute as its guiding spirit. The ob-

serving period, August 1, 1932, to August 31, 1933, was designed to be 50 years after the first polar year, and due note was made of the fact that this, unlike the former period, would be one of minimum solar activity. The objectives included investigations in the newer disciplines of ionospheric physics and cosmic-ray studies.

This second effort saw the establishment of 35 special stations by 20 nations, which, together with more than 60 regular establishments, made nearly 100 observing points. One was in Antarctica. J. A. Fleming and N. H. Heck of the United States served on the commission, and the major American contributions were magnetic, auroral, and ionospheric observations at Fairbanks and Point Barrow, Alaska, auroral studies in Greenland, and widespread weather observations.

The accomplishments included substantial progress toward understanding magnetic storms and other magnetic disturbances and associated auroral and ionospheric phenomena, and improved knowledge of wind and pressure systems in high latitudes of the Northern Hemisphere. A vast collection of data resulted, some of which still awaits types of analysis that only modern high-speed computers can provide.

BEGINNINGS OF THE IGY

The group in Dr. Van Allen's home in 1950, aware of the rapid advances in geophysics, especially in ionospheric investigations, perceived the desirability of a third and still greater effort, this time after a period of only 25 years and this time by design to coincide with another peak of the solar-activity cycle. It was recognized that the field of observation would be far wider than just the polar areas.

Sidney Chapman, then president of the International Union of Geodesy and Geophysics (IUGG) as well as of one of its constituent associations on terrestrial magnetism and electricity (IATME—later IAGA), and Lloyd V. Berkner, a member of the United States National Committee for the International Union of Scientific Radio (URSI), referred the matter to three international scientific organizations, of which the first to meet was the Mixed Commission on the Ionosphere (MCI), maintained by URSI with the cooperation of IUGG and the International Astronomical Union (IAU). The Commission, followed later by URSI and IAU, endorsed the proposal to the International Council of Scientific Unions (ICSU), a top-level coordinating body. In January 1951, ICSU commended the idea to its own executive board, which, in the following October, decided to form a special ICSU committee to run the show. This committee, which turned out to be of protean nature, together with other interested organizations, took preliminary steps resulting in several effective actions.

Nations adhering to ICSU were invited to form national committees to organize their own participation in the project. The polar-year

concept was broadened to encompass the world, since the phenomena originally considered characteristic of the polar regions were now known to be but intense manifestations of worldwide phenomena, and the new name "International Geophysical Year" was adopted. A geodetic project of the IUGG and URSI for a new world-longitude determination was included. The World Meteorological Organization (WMO) and later the International Union of Pure and Applied Physics (IUPAP) were welcomed to the company. Most important, by early July 1953, a full Special Committee for the International Geophysical Year (CSAGI) had been convened. In its first meeting, Dr. Chapman and Dr. Berkner were elected president and vice president, and Marcel Nicolet of Belgium was designated permanent secretary. The committee contained representatives of IAU, IUGG, URSI, WMO, ICSU, the International Geographical Union (IGU), and later IUPAP, suitably distributed by nationality.

The IGY was considered at first as being divided among 11 disciplines comprising such representative coverage of geophysics as meteorology, latitude and longitude determinations, geomagnetism, the ionosphere, aurorae and airglow, solar activity, cosmic rays, glaciology, and oceanography. The work was planned to be supported by a variety of constructive operations such as the choice and announcement of selected World Days for intensive observations, the organization of world data centers for the collection and dissemination of technical results, and a program of publication covering all aspects of the IGY. The eventual performance of the work followed generally along the indicated lines; however, there were some changes, such as the later inclusion of gravity determinations and seismology, and the organization in some countries of such specialized logistic or operational activities as polar expeditions (notably to Antarctica), rocketry, and earth satellite experimentation.

The original plan, subject to extensive later additions, dealt with broad objectives toward which the participating countries would work. In meteorology it included global atmospheric circulation, energy content and dynamics, ozone, cloud physics, and radio atmospherics and electricity. In geomagnetism the principal problems were the morphology of magnetic storms and transient effects, relations with the ionosphere, and the equatorial electrojet. Synoptic studies of aurorae, especially in relation to magnetic storms, were planned, as well as the betterment of auroral charts, spectrographic and photometric studies, and corresponding treatment of airglow phenomena. Ionospheric work was to include extensive recordings of layer heights, radio absorption and scatter effects, and galactic noises. Solar-activity work was to be intensified and to include observations of radiation, sunspots and flares, the corona, and general spectroscopy. Cosmic-

ray studies were important for their implications regarding solar and geophysical effects, especially in relation to magnetic fields of the sun, the earth, and space, and to cosmic-ray interactions with the atmosphere. Latitude and longitude work was directed to improve time determinations and star catalogs and to determine the irregularities of the earth's rotation. Glaciological and oceanographic work, originally considered not to be of synoptic nature, and therefore of minor IGY significance, eventually grew into major projects because of their importance in the heat balance and chemical problems of meteorology. Oceanography in particular loomed large because of the intimate relations of the oceans to many problems of weather and terrestrial dynamics and because of the vast natural resources of the oceans. Emphasis throughout was placed on worldwide views of all these geophysical phenomena, and particularly on intensive investigations in little-known Antarctica.

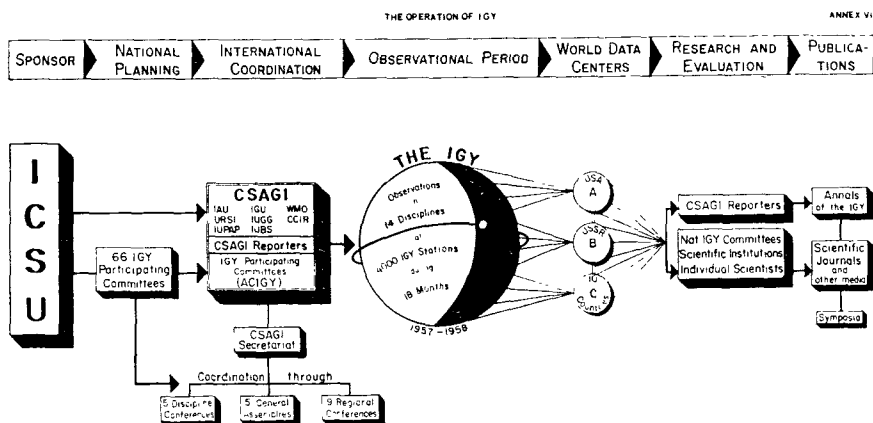


FIGURE 1

Inevitably many other detailed aspects of these disciplines, as well as entirely new and unanticipated problems, demanded attention before the IGY was even well started. While the original concept, derived from the polar-year experiences, envisioned a program concentrating on synoptic problems, secondary objectives presented themselves and were admitted to provide for types of work that would be facilitated by the basic IGY activities, or that could constitute epochal measurements for secular change studies.

ORGANIZATION OF THE IGY

One of the first aims of CSAGI was to enlist the cooperation of as many countries as possible—ideally all scientifically competent nations. At one of the formal meetings of CSAGI at Rome in 1954,

Moscow sent a delegation to announce the intentions of the Soviet Union to participate—a development of strong accelerating effect, since no less than 66 nations eventually joined. Another significant event occurred at Rome. Following shortly after initial recommendations from URSI and IUGG, the CSAGI group formally proposed that countries able to do so undertake to place artificial earth satellites in orbit for the uniquely valuable observations seen to be possible by such means. Thus geophysicists hoped to acquire otherwise inaccessible information bearing on the cause and formation of the aurora, on the fluctuations of the earth's magnetic field, on the roles of the solar ultraviolet, X-ray and particle radiation, and on cosmic-ray phenomena.

Flights of earth satellites and space exploration were soon to become realities in any event. It was nevertheless a direct result of the agreement reached at Rome that the United States and the Soviet Union embarked at this time on what was to become perhaps man's most adventurous scientific enterprise. It was of course destined to produce results far beyond the initial expectations of CSAGI.

In the United States a national committee was established by the National Academy of Sciences, headed by Joseph Kaplan, and functioning with a secretariat headed by Hugh Odishaw as executive director. This committee became the focus of a large structure of technical panels, geographical committees, and other special groups, including a broad cross section of leading American geophysicists. The National Science Foundation, under technical guidance of the committee, prepared budget estimates and obtained congressional appropriations with which the large U.S. program was funded. Great logistic and operational contributions were made also by defense agencies, particularly for Antarctic expeditionary activities and rocket and satellite work.

The IGY grew to the status of big business. Directly appropriated U.S. funds amounted to some \$43.5 million, and the estimated value of contributions from Federal agencies was in the order of \$500 million, including logistics, Antarctic operations, missileery, etc. The effort of the Soviet Union was evidently equal to, and may have exceeded, that of America. The contributions of numerous other countries were impressive too—in a number of cases greater in relation to population or national wealth than the U.S. effort. A loose estimate of the total contributions of all nations would come to something like \$2 billion.

THE SCIENTIFIC RESULTS OF IGY

No comprehensive account or full appraisal of the scientific results is yet possible. The IGY was primarily a period of observation and data gathering, and it will require years for the world scientific com-

munity to analyze so much material—masses of data not yet even collected in any one place. At this time we must be content, therefore, with some broad views suggestive of the scope of the work, with an indication of some major findings and a few of the implications. It is also impractical in a short account to refer to the many individuals and institutions deserving credit for what has been done.

In practically all disciplines the IGY work served dramatically to raise new problems and to broaden our realization of the vastness of the unknowns into which we are, so to speak, poking exploratory fingers. The IGY produced many more questions than it answered. Lloyd Berkner has said that it is like coming from outer space and finding a new planet.

The IGY investigations fit well into groupings based on major relationships between disciplines. One such scheme comprises: (*a*) The upper atmosphere, adjacent space, and solar influences; (*b*) the heat and water budget of the earth, comprising meteorology and related aspects of oceanography and glaciology; and (*c*) the solid earth.

PHYSICS OF THE UPPER ATMOSPHERE, SPACE, AND THE SUN

Interplanetary space suddenly became important—and useful. The IGY showed us much about it. We learned that there is no definite end to the atmosphere. In its vague outer regions, at perhaps 3,000 kilometers, it is almost indistinguishable from space itself. Solar and cosmic streams of elementary particles pass in undiminished intensity, forming with meteors the most important factors of the environment. The electrical and chemical activity of the upper atmosphere and of interplanetary space is due to X-rays and ultraviolet light, protons and electrons, meteors, and cosmic rays. There are present also electric and magnetic fields due to the movements of charged particles, and everywhere there is gravity, the weakest of known forces but perhaps the most important in the universe. Atomic hydrogen is also everywhere, in densities of perhaps 6 to 600 atoms per cubic centimeter. Previously unknown meteor streams were found, but the density of meteors and meteoritic dust, feared to imperil space vehicles, was found gratifyingly low.

Within 10 earth diameters there exists an actual hydrogen atmosphere, with a density at 500 kilometers as great as 100,000 atoms per cubic centimeter—this being ingeniously deduced from ultraviolet measurements made by nighttime and daylight rockets. Nearer the earth, atmospheric densities in the 200–500-kilometer band were found several times greater than previously supposed, as shown by observed retardation in the velocities of satellites. The density, moreover, exhibits strong variations supposedly due to the heating effect of particle collisions following solar bursts—this is suggested by satel-

lite perturbations unquestionably related to the 27-day solar rotation, to specific solar flares, and to geomagnetic activity.

The sun.—The sun, generator and moderator of the physical forces affecting the earth, became a primary focus of attention. More than 100 patrols maintained watch upon it nearly every minute of the IGY, and 30 or more observatories, including 7 in the United States, photographed the sun at 3-minute intervals, comprising in effect an unprecedented motion-picture study. A notable achievement was the new order of fineness achieved in the photography of the granulation of the sun's surface, employing a combination of telescope and automatic sun pointer from a balloon at 80,000 feet. Thus we have the most detailed solar record in history, and for the first time an almost complete record of hydrogen gas flares, the influence of which upon the earth's ionosphere ranks among the most dramatic events in solar-terrestrial relationships. Sudden effects, caused by the bursts of ultraviolet light and soft X-rays, are seen in magnetic recordings, fadeouts of shortwave radio, enhancement of atmospherics (radio static), and reductions in cosmic radio noise level.

The sun cooperated notably by achieving the highest level of activity ever known. On Christmas Day of 1957 the greatest number of sunspots occurred since Galileo first reported them in 1612. Flares abounded. From this fabulous record a drastically modified concept of sun-earth relationships and of the conditions of interplanetary space has been derived.

Many sources of solar radiation were identified. Remarkably fine and detailed photographs showed the ultraviolet light source to be in patches closely associated with calcium plages (flocculi or clouds). Solar hydrogen flares are identified as a source of gamma radiation. Radio emissions of thermal generation were confirmed from coronal regions at much lower temperatures than previously believed possible. Radio noise emissions, noted to be associated with optical flares and energetic proton flux, await full explanation. Balloon measurements during eclipses have indicated the corona to be the source of X-rays, possibly an important factor in the causes of radio blackouts—the most widely known and troublesome of solar effects. Strong X-ray flux was discovered at 60,000 to 90,000 feet during auroral displays accompanying ionospheric disturbances.

The magnetic fields of the sun are perhaps the most important problem in solar physics, since therein can be found the forces that accelerate the solar particles affecting space and our upper atmosphere. A main magnetic field of minor intensity exists, with the property of puzzling polarity reversals that are presumed to be associated with the dynamic conditions of solar material. Intense local fields accompany sunspots and flares, and correlations between changes of field

strength and flare occurrence have been found. Finely detailed mapping of the solar magnetic fields showed such small intensities as 1 gauss or less, with resolution in the order of 1 second of arc.

The corona is of vast extent and influence. Observations of electromagnetic waves of various frequencies from radio stars at times of near conjunction with the sun indicated a coronal structure aligned with residual magnetic fields out to distances of 20 or more solar radii. It has no definite limits and may extend indefinitely outward beyond the outer planets. It is believed to reach $7,000,000^{\circ}$ F. in some parts, and Sidney Chapman has speculated that much thermal energy is, in fact, transferred to the earth's atmosphere through direct contact with the thin but hot gases of the corona, perhaps at $350,000^{\circ}$ F.

Radiation belts.—Space, we have seen, is far from empty. Among its features are the Van Allen radiation belts, intrinsically remarkable as well as an outstanding IGY discovery. Based on almost fantastically sparse probing up to the time of this writing, these two belts were tentatively described as annular shrouds about the earth, shaped by the typical force lines of the terrestrial magnetic-dipole field, and having northern and southern terminal cusps or edges pointing inward toward the auroral zones. Totally unexpected radiation intensities blocked the initial rocket probes with impossible counting loads, until Van Allen, with brilliant insight, provided modified counters. The vast outer belt of relatively soft, low-energy particles is most strongly developed in the zone between 3 and 4 earth radii distant from the earth's center, with maximum intensity perhaps in excess of 25,000 counts per second. It consists of charged particles—protons and electrons—captured by the geomagnetic field from clouds of plasma spewed forth from the sun. The inner belt, 2,200 to 5,500 kilometers from the earth's surface, consists of very high-energy particles of an origin yet unknown but suspected to be the decay products of cosmic-ray collisions. The particle count is somewhat lower than that of the outer belt. It has been said that despite the vast extent and intensity of the Van Allen belts, which would require billions of X-ray machines to duplicate, the materials present would amount to perhaps one-fifteenth of 1 ounce of hydrogen! Not enough is known about the identity and energy of the particles to provide good estimates of the radiation intensities.

The implications are tremendous. Notwithstanding our slender knowledge, it appears that the energy budget of the outer atmosphere and the theory of magnetic storms and aurorae will be dominated by these belts. Their presence means that many types of instruments must be shielded and that severe problems may confront human space travelers, although little is yet known of the biological effects. (It is because of this that one hears suggestions that future space voyagers

may have to take off from the polar regions, escaping, so to speak, through the hole of the doughnut.) An interesting possibility is that similar belts may become useful as aids in detection of magnetic fields of other planets.

Cosmic rays.—Cosmic rays are another important factor of the space environment, with various consequences for the earth. They are charged particles of ordinary matter like those propelled from the sun, but generally of cosmic origin and of vastly greater energies—some are believed to travel at speeds near that of light and to carry energy up to 10^{19} electron volts—a billion times that achieved in man's best particle accelerators. They may represent half of all the energy in the universe. Through rocket and satellite observations, we know that such high-energy, or primary, cosmic rays are characteristic of space above the atmosphere and that in collisions with atmospheric molecules they produce showers of breakdown products of lower energy, called secondary cosmic rays, which reach lower levels. The sun has been found to influence cosmic-ray behavior near the earth, confronting us with an important factor in the study of magnetic space fields and magnetic storm effects. Cosmic rays display diminished intensity in general during sunspot activity, but there are shorter period fluctuations not so related. High-altitude aircraft observations of cosmic rays provided evidence leading to some refinement of our ideas about the configuration of the geomagnetic field at those and higher altitudes.

High-atmosphere phenomena.—Our outer atmosphere is thus under radiation of various types—X-rays, ultraviolet light, hard and soft cosmic rays, and charged particles from space or the radiation belts, which enter along lines of magnetic force. A whole family of related phenomena results. Under radiation the atmospheric gases produce the luminous effects of aurorae and airglow. Ionization of the thin outer gases occurs in layers comprising the ionosphere. These sheets of ions reflect or refract electromagnetic waves, providing the basis of long-distance radio communication, and they support electric-current systems and magnetic fields in grand patterns.

When the radiation becomes irregular, as at times of solar disturbances, the ionization is chaotic. Radio signals fade or black out, and the changing magnetic fields produce geomagnetic unrest and magnetic storms. Solar activity, radio-wave propagation disturbances, auroral displays, and magnetic storms had therefore to be considered together in broadly comprehensive views during the IGY.

The ionosphere.—This feature is in fact a series of concentric shells of ionized gases about the earth in configurations determined by the gas densities and chemical compositions. IGY observers carried out continuous intensive monitoring of the ionosphere, using vertical-inci-

dence and oblique radio probes or soundings from the ground to determine ionospheric conditions by echo recordings. They observed radio-wave propagation characteristics under all manner of conditions, and they sought to find the extent, magnitude, and location of electric currents comprising streams of the ionized particles.

The ionospheric electric currents are particularly intense and complex in the auroral zones, but they exist everywhere in some form. Interesting features of local ionization and a strong electric current were found in the close vicinity of the magnetic equator. Much was learned about the neutral and ionized gases of the ionospheric regions—helpful information in the problem of determining the best working radiofrequencies to suit conditions. Scatter propagation of radio waves, often useful despite disturbed conditions, was studied intensively. Among the techniques responsible for such findings were geomagnetic studies and the analysis of radio signals from earth satellites.

Geomagnetism.—The geomagnetic program of the IGY was directed mainly toward the investigation of magnetic storms and other transient phenomena related to the ionospheric electric currents. Special arrays of recording stations were used to discover the dimensions of the magnetic fields in question, and thus to describe the current streams and systems. Among such arrays were ingenious “differential magnetographs” designed to record the field gradients across station arrays continuously as they fluctuate.

Stations in several places close to the magnetic Equator strongly indicated the intensity and extent of the previously mentioned equatorial electrojet—a powerful concentrated stream of current almost precisely along this zero-dip line. It exists chiefly on the sunlit side of the earth, and it must result from ionization by ultraviolet light or X-rays, rather than by energetic particles, which presumably cannot cross the magnetic field lines to that region. Electron and ion counts were made in the body of the current by rocket firings. The circuit return mechanism has not been determined.

The large number of special IGY magnetic observatories, particularly in Antarctica and other new places, provided working material for extensive investigations into many aspects of natural electric and magnetic phenomena and their relation to solar events. For the first time they furnished evidence of essentially simultaneous worldwide magnetic effects, and served to round out our global concepts. Telluric currents (in the earth’s crust), the result of induction from the ionospheric currents, were found in unexpectedly great intensity and wide distribution, finely dissected by local ground conditions. The combined effects of ionospheric and telluric currents posed complex new problems impeding analysis attempts.

Pioneer work was done to disclose the secrets of geomagnetic field oscillations in the range between 1 and 100 cycles per second—a new area of research. Other experiments were designed to shed new light, if possible, on the old and unresolved question whether any real correlation of meteorological and geomagnetic effects exists. The Russian nonmagnetic ship *Zarya* discovered many unknown magnetic anomalies in ocean depths. Meanwhile, the main magnetic-field anomalies were said by Russian magneticians to be features of the depth of homogeneous magnetization, ruling out ferromagnetism of the crust as a source.

Aurora and airglow.—Auroral studies, difficult in a sense because by nature they do not submit to quantitative analysis, have nevertheless been prominent because of the public interest in the auroral displays and because amateur contributions are possible on a wide scale. The program included photography of various kinds, spectroscopy, position-finding observations, studies of extent and simultaneity, and even probes by rocket shots.

In general, it was found that aurorae are continuous throughout the extent of an isoclinic or magnetic dip line on the dark side of the earth. Motions within the aurorae progress from west to east—in this respect providing an unanswered mystery.

A variety of nonpolar and less spectacular aurora is the airglow. Solar energy is stored, as in a huge chemical reaction chamber, in the outer fringes of the atmosphere, where the energy synthesizes many chemical compounds. These gradually decay, emitting light, the wavelengths of which indicate the particular reaction. On moonless nights, the luminescence may contribute substantially to the night light—perhaps as much as the stars themselves. The airglow is many times stronger in the hours when the upper atmosphere can receive direct sunlight. The program for its study included expanded networks of ground stations as well as instrumented rocket flights for the exploration of the levels at which the various spectral lines are generated. Vast energy is involved which man may one day utilize with sufficient understanding of the circumstances.

Auroral displays may become very widespread following violent solar events, as in the case of the outstanding solar flare of February 9, 1958. This flare and its consequences were among the most intensively observed cosmic phenomena of all time and may have been the most important single event of the IGY. One day later, on the 10th, auroral displays as high as 800 kilometers and visible as far south as Cuba followed the entry of the earth into the great plasma cloud produced by the flare.

Protracted worldwide disturbances to communications by radio, as well as by land telegraph lines and ocean cables, accompanied this

disturbance. The play of magnetic fields in the upper atmosphere induced potentials in transatlantic cables as great as 2,650 volts. From the moment of discovery of the original flare until the return of normal conditions several days later, all IGY scientists interested in space and the upper atmosphere had unexcelled opportunity to make coordinated observations, demonstrating the high value of the synoptic approach.

Artificial radiation effects.—An event of great interest, but not part of the IGY, showed, on August 1, 1958, that atomic bursts in the ionospheric regions are capable of producing artificial radiation and other widespread effects matching those of Nature itself. A nuclear explosion was produced by the United States in the ionosphere over the Pacific near Johnston Island, and within 1 minute a visible aurora was observed at Samoa—the first time in history! Simultaneously, Hawaii was aroused by a brilliant flash of light. Strong magnetic disturbances were recorded on the magnetographs at Honolulu, Samoa, Palmyra, Fanning, and Jarvis Islands. Radio blackouts of circuits over a large Pacific Ocean area persisted for one or more days. The radiation was detected and reported during many hours by the earth satellite Explorer IV during its passages over the area. Another such explosion at lower height 11 days later produced somewhat similar results.

A significant circumstance is that the location of the blasts and the vicinity of the Samoan aurorae are conjugate points respecting the geomagnetic lines of force. Charged particles introduced into the field at one of the points would predictably reenter the atmosphere at the other, as occurred at Samoa. Such controlled tests tell much about hitherto inaccessible phenomena.

A similar but even more dramatic demonstration was made, by definite design, in late August and early September 1958, when three small nuclear devices were exploded by the United States above the South Atlantic in the near vacuum of a region of relative minimum of natural radiation between the Van Allen layers. Immediately there were seen streaks of auroral luminescence along the magnetic lines of force, and a brilliant aurora was observed at the conjugate point near the Azores, where the particles, after spiraling along the lines out to distances as far as 6,500 kilometers into space, reentered the atmosphere. Theoretical predictions of the external figure of the geomagnetic field were verified. Following the now famous predictions of N. C. Christofilos, energetic particles immediately dispersed in a shell determined by the geomagnetic field, where they persisted during the battery lifetime of the satellite Explorer IV until late September. For the first time in history worldwide measurements were made on a completely controlled geophysical phenomenon, wherein a known

quantity of electrons of known energies was injected into the earth's field at known times and places.

Another highly specialized investigation was directed toward the so-called whistler phenomenon. This involves the observation of electromagnetic radiation from lightning discharges, which similarly follows magnetic lines of force in the presence of a radiation field, to be heard finally through radio receivers at the conjugate points as rising or falling whistle sounds. This is explained as being due to differences in the propagation rates of the different radio frequencies produced by a lightning discharge. Unaccountably, however, whistlers have in some instances been heard over widespread areas not conjugate to each other; hence the radiation is not necessarily confined to magnetic-field lines.

New tools of man.—The use of rockets and earth satellites has in itself been a dramatic technical achievement, aside from the great value of the observational data so acquired. Ushering in, as they do, a new age of scientific exploration, they now provide exciting prospects of adding to human knowledge. Among the future objectives may be mentioned the further study of heat radiation, earth cloud cover, gravity and magnetic fields, the composition and processes of interplanetary media, life processes, the atmospheres, ionospheres, composition and structure of the planets, new fields of astronomy, solar nuclear processes, and the validity of Einstein's general relativity. As this is written plans are afoot to conduct a "clock" experiment, to determine by use of atomic clocks in space probes whether time goes slower with speed of the observer.

THE HEAT AND WATER BUDGET OF THE EARTH

Weather and climate are among the most immediate preoccupations of man. In everything that he does, but especially in his activities in the fields, on the sea, and in the air, it exerts controlling influences over his very life and death. This, then, is nothing esoteric or "scientific" to the common man—it is his daily concern, and herein the IGY comes closest to his understanding.

Studies bearing on weather have historically suffered from a paucity of worldwide simultaneous data. The highly transitory and vastly complex phenomena of weather constitute the very prototype of a problem demanding the synoptic approach. The requirements are instantaneous pictures of the state of the whole atmosphere and broad vistas of the patterns of its activity everywhere on earth. These the IGY undertook to approach as nearly as possible, and thus meteorology became the greatest single sphere of IGY investigation.

Meteorology.—History's most effective steps toward the ideal of worldwide simultaneous data were taken in the IGY. For the first

time it became possible to compile reasonably detailed pole-to-pole cross sections and synoptic charts. This was achieved by the establishment of three standard meridians—10° and 140° E, and 70° W—along which the participating nations concentrated their observing stations; by the opening of Antarctica to observation; and by a general intensification of station layouts everywhere. These improvements in coverage, and the relentless penetration of the stratosphere by soundings to new heights, are rapidly advancing the state of scientific meteorology.

Perhaps the most important IGY contribution to meteorology was the weather study of Antarctica. That bleak land has the world's coldest weather—a low temperature of 125.3° F. below zero is on record—but not all of Antarctica is that cold. Differences in the winter temperatures of portions of the continent equal those between Miami, Fla., and the Arctic. Old incorrect theories of the air circulation were laid at rest, and fundamental contrasts with northern polar weather were found.

The intensely cold air reaches perhaps only 1 kilometer above the ground; at greater heights the readings range 50° and more upward. It is accordingly believed that the Antarctic is not the major reason for the generally colder climate of the Southern Hemisphere. There are marked seasonal fluctuations of the stratosphere within a range as great as 150° F., a circumstance of high significance in the study of widespread climatic processes. The Antarctic stratospheric cyclone, unlike its mobile Arctic counterpart, tends to linger near the South Pole.

Air circulation is one of the main ingredients of the picture. It is now known that the Antarctic Continent presents no barrier to the free flow of tropospheric winds clear across the continent, distributing heat and moisture and greatly slowing the temperature fall during the polar night. In contrast, the stratospheric airmasses appear to be sealed off by a strong jet stream encircling the continent; thus its temperature drops continuously in the winter.

Important help in the exploration of upper air movements was afforded by modern balloon-borne radiosondes capable of reaching great heights. Natural radioactive tracer elements, such as tritium, also provided valuable clues. Worldwide circulation patterns exist. It was found that multiple jet streams at 9 to 12 kilometers exist even in high latitudes. Aside from research value, such information has already facilitated high-level jet-aircraft operations.

A great deal of investigation was carried out to determine atmospheric temperatures and the content of water and other compounds such as carbon dioxide and ozone, which have significant parts in the general mechanics of weather. The oceans, source of most of the

water and much of the heat energy, were critically examined to determine their temperature characteristics and the circulation of their waters. For the first time, for instance, we have a full year of observations of temperature and salinity to 100 meters and of tides and sea level all the way across the Pacific from South America to Australia.

Among many special problems were such questions as the ocean-water absorption of carbon dioxide from the atmosphere, as well as the concentration of that gas with height. It has been suggested lately that the worldwide carbon-dioxide concentration is increasing, by the burning of chemical fuels in man's engines, at such a rate that noticeable climatic changes, if not already upon us, are soon to be detected. This follows from the so-called "greenhouse effect." Atmospheric concentrations of carbon dioxide do not interfere with heat intake but inhibit infrared reradiation, thus conserving heat energy and producing a general warming up. Little America now has a mean temperature 5° F. warmer than when first occupied in 1912, while that of Spitsbergen has risen 11° F. in the same time. Climatic studies showing mean temperature increases, and other evidences such as glacier recession and the northern migration of warm-climate fauna, bear out this supposition.

Ozone, the 3-atom form of oxygen, is present in substantial concentrations, known to have some relationship with that of carbon dioxide. Ozone traps the extreme ultraviolet radiation which otherwise would interfere with the organic life of the earth. Ozone transport is not fully understood, but it is known to be related to the general circulation and to be useful, therefore, as a tracer element.

With the impact of increased observations, better theories and high-speed computers, meteorologists are developing more certain weather-prediction capabilities. It has been said that better and long-range weather forecasts would be worth \$100 million to the petroleum industry alone. The value to transportation, business, and agriculture cannot be imagined.

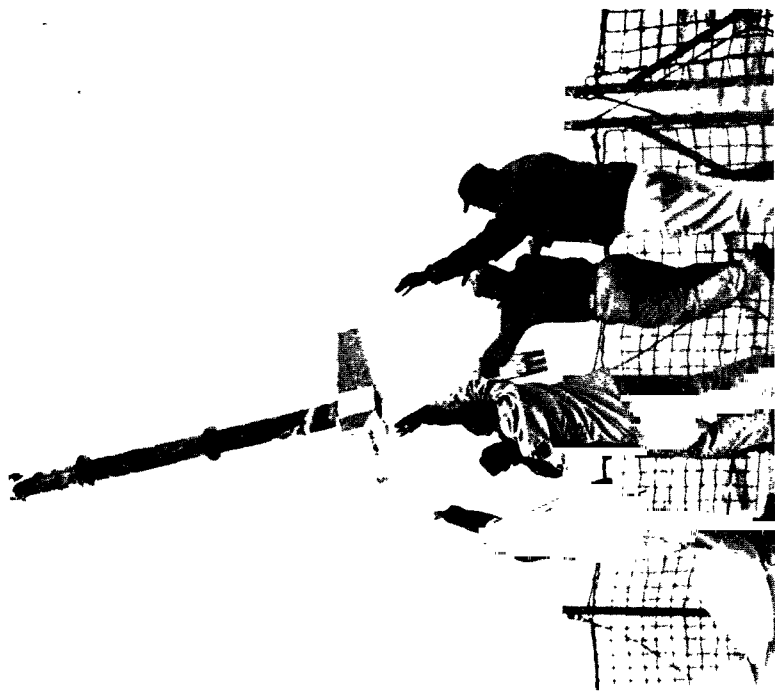
A vital factor in forecasting is the general synoptic view of water content, seen in part, at least, as cloud cover, and an important development in modern meteorology is the weather robot, a cloud-scanning earth satellite. Such a device provides a comprehensive picture showing the extent and distribution of cloud cover at one time over the whole earth. Post-IGY satellites have achieved brilliant success in this undertaking. Similiar techniques will show the wind patterns, weather fronts, rain pockets, airborne gases, and temperatures. They will measure the heat soaked up by the earth from the sun and how much is discarded in turn. This information is of great value in supplementing the reports from thousands of ground stations, which



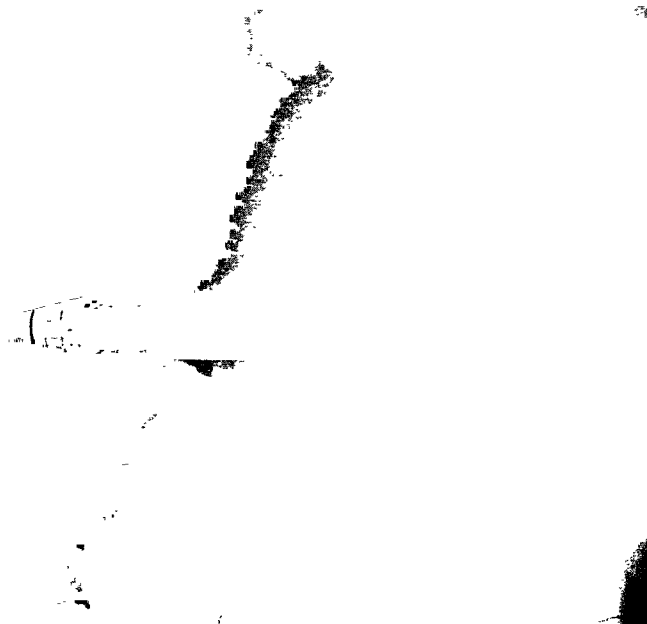
1. Scanning photometer on Fritz Peak, Colo., for measuring the intensity of airglow and its changes. (Photograph courtesy National Bureau of Standards Boulder Laboratories.)



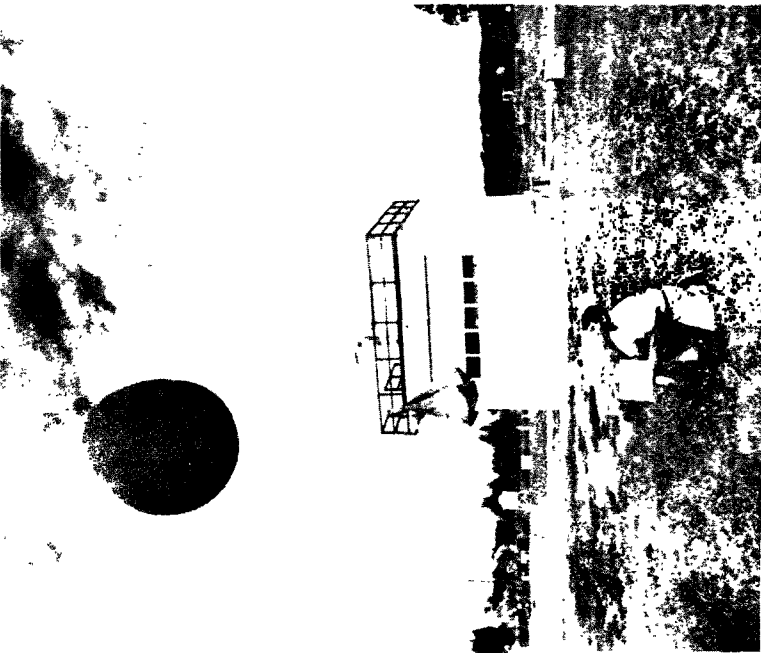
2. Digging out at IGY Little America Station after the winter of 1957. The rawin tower dome is in the background. (Official U.S. Navy photograph)



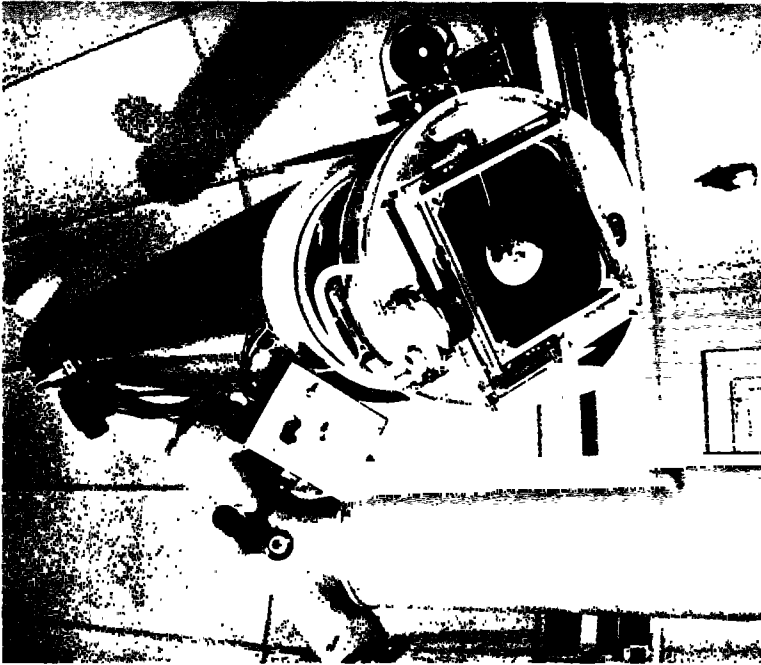
2. Rocket launching aboard ship. The Deacon rocket, used for upper-atmosphere studies, is carried aloft by a balloon before it is fired. (Official U.S. Navy photograph.)



1. Pioneer IV being launched into a heliocentric orbit at 12:11 a.m. EST, March 3, 1959. (Official U.S. Army photograph.)



1. Launching a balloon-borne rawinsonde assembly for meteorological observations. Radio receiver is under fiberglass dome atop the inflation shutter. (Photograph courtesy National Academy of Sciences.)



2. Dual-rate moon position camera and telescope, for precise determinations of latitude and longitude on the earth. (Photograph courtesy National Academy of Sciences.)

altogether cover less than half the earth's surface, and in tying these observations together to reveal patterns unsuspected by the ground observer. Better storm warnings and longer-range forecasts will result.

Many leading meteorologists believe that man's growing knowledge of atmospheric physics, and the acquisition of tremendous energy resources, will one day give him the power to control the weather. It is unnecessary to suggest the consequences for both peaceful pursuits and war activities. When it does happen, we can reflect that the IGY played a major role in producing such revolutionary changes in the human environment.

Oceanography.—The seas, last geographical frontier on earth, prevent easy access to some 71 percent of the surface of the globe. They have borne the ships of the world since the dawn of history. Alexander the Great went down in a diving bell, yet man has but recently begun to explore them on a large scale. Now suddenly they are placed in a bright new limelight. Oceanic waters exchange water and energy with the atmosphere, producing major effects upon the weather and climatic cycles of the earth. We are told that they could provide more organic food materials than all the land areas of earth put together; on the other hand, they are perhaps a menacing frontier threatening submarine-launched missiles against our cities. All at once we have a need to learn everything about this well-nigh limitless environment, and to survey it forthwith. It is already trite to repeat that we know less of the ocean floor than of the visible surface of the moon. Thus the IGY embraced oceanography without restraint and it is just the beginning—a committee of the National Academy of Sciences has recommended an American oceanographic research program estimated to cost the Nation two-thirds of a billion dollars within the next 10 years.

As in the case of the atmosphere, the circulation within this great body of fluids had to be investigated, for tremendous thermal, chemical, and kinetic energy is involved. Indeed, ocean-water circulation may well be a clue to many mysteries of the weather.

The ocean is a complex layered structure with mighty rivers on diverse and mostly unknown courses, and with areas of turbulence and upwelling. Exploration of the circulation patterns requires ships and many instruments, including current meters, and some help is given by the evidence of radioactive tracers. Three major countercurrents have been investigated. One lies 9,000 feet below the Gulf Stream, traveling south at some 8 miles a day. Long known to exist, it took the IGY to provide definition of its characteristics. The Cromwell Current of the Pacific was discovered as late as 1952. Occupying a broad band south of the Equator, it flows east 200 to 1,000 feet

below the westward drift known as the South Equatorial Current. It transports a billion cubic feet of water per second at 3.5 miles an hour. Even this prodigious movement is exceeded by the Pacific Equatorial Countercurrent, 200 miles north of the Equator, which carries eastward half again as much—the equivalent of more than 2,000 Mississippi Rivers! Oceanographers have not yet explained where all this water goes when it reaches the American Continent.

The sources of great water masses must be known in studying the general circulation. The ice caps of Antarctica and Greenland, and smaller glaciers everywhere, obviously provide substantial amounts of water. (Many persons are by now familiar with the statement that if the Antarctic ice were to melt completely the oceans would rise some hundreds of feet above present levels—luckily, a matter of no immediate hazard.) Analysis of the deep waters of the Atlantic shows staleness and oxygen starvation as compared with 30-year-old observations. This suggests a lessening in recent years of cold polar water to carry fresh oxygen to the depths, a matter of concern in marine biology. Anomalous warm-water masses in the Pacific in recent years have been accompanied by unusual fish distribution and by apparent effects on climates, but the causes are not yet explained.

The dynamic motions of the sea surface have had comparable attention. The U.S. island observatory program employed sensitive wave-metering devices and an unusual distribution of standard tide gages. Much information was derived leading to the analysis of water levels and the identification of short- and long-period waves up to several minutes in period, sea surges as much as an hour long, and other dynamic effects. Some of the motions may be related to tidal and earth-rotational mechanics; others are clearly meteorological in origin, with evidences of energy coupling between the water and atmospheric pressure systems even as high as the stratosphere. Possible benefits may be the future prediction of storms and damaging waves. Basic information was obtained about the steric sea level, which depends on total water volume, and we now have a growing idea of the changing shape of the sea surface during the period of the IGY.

Gropings toward that other boundary, the bottom about which so little is known, derived important facts of several kinds. Deep trenches and a 1,000-mile range of sunken mountains were found in the Pacific. The mid-Atlantic ridge was more extensively explored, and its geological substructure probed with sound waves from underwater explosions—a process termed “seismic exploration.” Large Pacific areas were examined minutely with ship-towed magnetometers, which found magnetic characteristics of the bottom rocks having great significance in the compilation of geologic and tectonic history. Tests indicated that the flow of heat energy from the crust into the

oceans is substantially larger than formerly thought—still another factor in the heat-engine cycle. Perhaps the most immediately interesting of the ocean-floor discoveries was a scattering of iron and manganese nodules, mixed with nickel, cobalt, and copper, over millions of square miles of the southeast Pacific, in concentrations worth hundreds of thousands of dollars per square mile. The economics of dredging appears promising.

Glaciology.—Like a smaller and less mobile counterpart of the sea, the ice deposits of the world store, and eventually release, water and thermal energy. Thus, they contribute their part to the endless cycle of weather and ocean phenomena. They also constitute valuable records of the past.

The ice in Antarctica is 40 percent greater than formerly believed but is now diminishing. It averages 10,000 feet in depth and contains 90 percent of all the ice in the world, some $6\frac{1}{2}$ million cubic miles. In many places on the high icy plateaus, 10,000 feet and more above the sea, the ice has been found by seismic prospecting methods to rest on underlying earth thousands of feet below sea level. Such discoveries show that we may have there a great archipelago instead of a single land; however, the IGY seismic explorations indicate a crustal structure of continental type. Perhaps it is a "founded continent." It seems likely that removal of the ice would disclose a broad strait between the Weddell and the Ross Seas, cutting Antarctica into two major land masses.

Ice borings in Greenland and Antarctica have reached layers formed by the precipitation of more than a thousand years ago. These layers can be read like tree rings, and the thermal insulation is so good as to have preserved the temperatures of past centuries. Ancient climates are thus known, and clues to the future may be deduced. This is one of the ways in which we know of warming trends of world climates.

We know, through observation of precipitation rates, that the Arctic has twice the snowfall of Antarctica. Pollen traces in perfect preservation and ash deposits at certain levels attest the atmospheric impurities of former times, and may give clues to ancient volcanic activity.

Glaciological studies of the great ice caps and smaller glaciers throughout the world provided first steps toward an understanding of the regimen, behavior, and physical properties of the great volumes of water withheld by climatic conditions from free circulation. An understanding of heat balances and interface reactions was gained. It was learned that glacier behavior throughout the world is synchronous—recession is going on everywhere. Incidental results were the creation of a corps of world scientists willing and able to endure the rigors of polar work and life, and in Antarctica, at least, a

demonstration that scientists of competitive political regimes can work cooperatively without fighting over questions of land ownership or jurisdiction.

THE SOLID EARTH

Solid-earth aspects of the IGY program included geodesy, gravity, and seismology, with overtones of oceanography, glaciology, and the flights of earth satellites. These subjects, unlike those dealing with transient phenomena which call for synoptic treatment, found places in the enterprise because they fell within the logistic resources organized for other IGY activities or because they could provide measurements of importance. Some results were fortuitous, as when geodesists found the orbital characteristics of satellites divulging unique information about the figure of the earth. The organized programs in the solid-earth subjects were relatively small, and much of their technical results requires extensive study; few important implications, therefore, have yet come to light.

Geodesy.—The framework of international cooperation established for the IGY was seen at the outset to favor establishing a new and better measure of the longitude differences between continents and major isolated island groups, such as Hawaii. This was realized through use of new instruments and techniques, including the American dual-rate moon camera, which provided new precision in the relation of terrestrial positions to the celestial firmament. Better absolute knowledge of geographic locations of the earth's landmasses was obtained, with advantages in mapping, operation of earth satellites, scientific studies of the earth, and the mechanics of its rotation, including problems of timekeeping.

The incidental geodetic value of earth-satellite orbital observations, particularly of Vanguard I, has been substantial. Observations on such relatively near and fast-moving celestial bodies with well-determined orbits permit a new and higher order of positioning of isolated points beyond reach of the geodetic survey networks of the world. Analyses of orbital perturbations reflecting the irregular distribution of the earth's mass have already indicated that the theoretical or mean figure of the earth may be unsymmetrical—slightly pear shaped rather than ellipsoidal, although the dissymmetry is very small. Active planning is in progress in the United States for the launching in the near future of geodetic satellites carrying special instruments in selected orbits designed for the fullest exploitation of these possibilities.

Gravity and seismology.—These fields of study profited by the strong upsurge of interest in geophysics and the many fieldwork opportunities produced by the IGY. They contributed in unique ways to our knowledge of the structure of the earth. New gravimeters, faster and more portable than the classic pendulum appara-

tus, permitted widespread detailed surveys of the earth's gravity field, supported by gravity surveys made in the search for petroleum. Thus are disclosed the effects of irregular earth-mass distribution, not only of mountains and ocean deeps that we can see but also of hidden ore bodies and structural irregularities of the earth's rocks. The new gravimeters are free of some of the limitations on use of the pendulum and have even been refined to cope with the accelerations of ship motion. Thus we may make gravity surveys of the watery three-fourths of the earth. It is believed, moreover, that airborne gravimeters will soon be an actuality.

The gravimetry program, aside from general survey coverage and the accomplishment of several important Antarctic profiles, dealt with the problem of earth tides, in the measurement of which gravity observations play a leading part. Gravimeters are sufficiently sensitive to indicate not only the changes in the lunar and solar tide-producing forces but also the small changes in distance involved in the rise and fall of the earth's crust. Such motion at Washington is nearly 6 inches in amplitude. Thus the gravity work contributed to our knowledge of the elastic constants of the earth and its crust, as well as of world mass distribution.

The gravitational force, which man has learned to measure with exquisite precision—one part in a million for absolute determinations, and a hundred times better for relative measurements—remains a scientific mystery, its true nature hidden somewhere outside man's conceptual capacity.

Seismological work also was stimulated by the unusual opportunities to place seismograph recorders in neglected parts of the world, particularly the polar regions. In the Arctic and sub-Arctic many gaps in coverage were filled, mostly by Soviet scientists. Antarctica, an aseismic continent except for one or two minor shocks a year, was nevertheless notable for its valuable readings on a broad range of far-southern quakes and for its clues to the seismicity of a vast region. Numerous readings of earth waves from Japanese shocks, agitating the seismographs after traveling the longest all-oceanic wave paths on record, helped in the determination of travel velocities through oceanic crustal formations.

A specialized application of seismology, in which reflected waves from small explosions on the surface are used to discover subsurface structure, disclosed the ice depths in Antarctica and Greenland, and indicated the continental structure of Antarctica. Similar exploration of the Andean massifs in South America showed that the underlying crust is unexpectedly thin, contrary to the normal expectation of a deep root structure.

Seismologists began the intensive development of seismographs sensitive to ground waves of ultralong period—waves which have

already demonstrated unique value in the detection of distant earthquakes and subterranean explosions.

CONCLUSION

Sheer masses of data were collected in the IGY. The United States alone has brought out no less than 17 tons of records just from its Antarctic stations. The total for the world is almost beyond comprehension. Now, to exploit such a fund of new information, we have comprehensive programs for its international exchange and for its orderly keeping in world data centers. There are new translating services, directed especially toward the large mass of Soviet-bloc science writings. General geophysics information in America is available in permanent journals such as *Transactions of the American Geophysical Union*, *Journal of Geophysical Research*, and *IUGG Chronicle*, and the temporary IGY journals, *Annals of the IGY* and *IGY Bulletin*. Complete technical data are available in the world centers.

The store of knowledge already amassed is great. It includes the story of Antarctica's striking geological history shown through the evidence of petrified trees and coalbeds. We have learned that the oceans may become a primary food source, "farmed" by man, and that their dark reaches may deliver up vast new riches for his benefit; that knowledge of solar processes may revolutionize our approach to energy problems; that space is far from a vacuum, but that despite its logistics problems and radiation hazards we will complete its conquest. The list could be well nigh endless. And we have yet far to go with the digestion of IGY data.

To keep us from straying into scientific fantasy, we have a legacy of planning bodies at national and international levels—committees for oceanographic and polar research, and our Space Science Board—which will point out opportunities for the fullest exploitation of the possibilities.

The scientific fruits we have seen to be great. Yet it may be hard to say whether less tangible values may not be even greater. We have the lesson that science is not parochial—that we must deal broadly with interdisciplinary problems. We know now that men of all races and political faiths can work together. The press of the world has produced a radical change in public attitudes (with no little help, to be sure, from the Russian sputniks). There is a burgeoning public awareness of the importance of science and of scientists. The scientist is losing his reputation for wearing long hair and going absent-mindedly through life. And we may now, for once and all, have laid the ghost of that stupid old question whether research and pure science are worth their own support.

Astronomy From Artificial Satellites¹

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[With 4 plates]

THE ELIMINATION of the earth's atmosphere as a barrier to observation has been dreamed of by generations of astronomers who have attempted to survey the universe from the bottom of a dirty and turbulent ocean of air. Considerable improvement is effected when observatories are placed on high mountain tops, far above fogs and low-lying clouds. At heights of 1 to 2 miles above sea level, where such observatories are located, the air is very pure, but no matter how pure, it is still air and therefore subversive of the goals of astronomy. It is only by placing telescopes completely above the earth's atmosphere that the astronomer can obtain a clear and unobstructed view of the heavens. It now seems certain that such an extraterrestrial observatory will soon be an accomplished fact, thanks to the achievement of artificial satellites, the most exciting advance in observing technique since the invention of the telescope.

There are three major reasons why the atmosphere is a hindrance to astronomical research. First, even the very tiny amount that is present above a height of several miles is completely opaque to all ultraviolet radiation of wavelength shorter than about 2,900 Å., and to much of the infrared radiation of longer wavelength. Second, the air is never completely steady even above high mountains. Local fluctuations in temperature induce violent currents of boiling air which distort the images of celestial bodies. The turbulence of the air has been responsible for the sharp difference of opinion concerning the nature of small details on the surface of the sun and for heated arguments as to the reality of the canals on Mars. Third, the atoms and molecules in the atmosphere scatter sunlight by day, and also emit radiation, which is visible by night. The bright daylight sky obliterates the faint light from the solar corona, and the airglow at night masks the radiation from the background of faint stars and

¹ The 25th annual James Arthur lecture on the sun, given under the auspices of the Smithsonian Institution, Oct. 23, 1958.

galaxies, the observation of which is so important for the understanding of the structure of the galaxy and of the universe beyond.

The turbulence of the atmosphere is not a serious factor at heights greater than about 50,000 or 60,000 feet. Hence, its disadvantages can be overcome by observations from high-altitude balloons, as has been beautifully demonstrated recently by A. Dollfus in France and by M. Schwarzschild in the United States. But the airglow and the absorption of ultraviolet radiation occur at very much higher altitudes which can only be traversed by rockets.

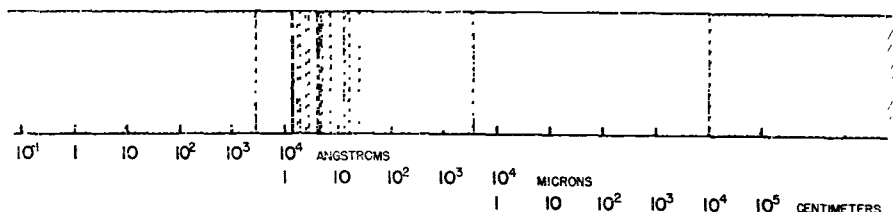


FIGURE 1.—Regions of the radiation spectrum blacked out by the earth's atmosphere (cross-hatched areas). Wavelengths are shown in angstroms, microns, and centimeters.

The problem posed by the absorption of radiation in the atmosphere is illustrated in figure 1. The astronomer investigates the physical nature of objects in the universe by analyzing the electromagnetic radiations which they emit. The sun, the stars, and the nebulae are aggregations of gas in which the temperatures range from a few thousand to a few millions of degrees. Gases at such high temperature will emit radiation of all wavelengths, which, for X-rays, are as short as a few billionths of a centimeter, or for radio waves, as long as tens and hundreds of meters. With the aid of optical and radio spectrometers, the astronomer sorts out the radiations of different wavelengths and arranges them in a spectrum in order of increasing wavelength. The measurement of intensity at each wavelength provides the basic observational data which are required for the physical investigation of the sun and the stars. Ordinarily, the wavelengths with which we are concerned are so small that special units of length must be introduced. For example, the wavelength of visible and ultraviolet radiation is usually given in angstrom units, 1 angstrom being equal to 1 hundred-millionth of a centimeter, whereas for infrared radiation, the micron, or 1 ten-thousandth of a centimeter, is usually employed as a unit of wavelength. Thus, X-rays are included in the range from about one-tenth to 100 A., ultraviolet radiation from 100 to 4,000 A., visible radiation from 4,000 to 8,000 A., infrared from 1 micron to 1 millimeter, and radio waves from 1 millimeter on up to hundreds of meters.

The cross-hatched areas denote those regions of the spectrum to which the earth's atmosphere is completely opaque from the ground.

No radiation of wavelengths shorter than about 2,900 Å. ever reaches the surface of the earth, either at sea level or at the tops of high mountains. The absorption of ultraviolet radiation and X-rays is caused by atoms and molecules of nitrogen and oxygen and by molecules of ozone which are created by the action of sunlight on oxygen molecules. At infrared wavelengths, the atmosphere is partially transparent in a number of so-called wavelength "windows" from about 1 to 24 microns. A small amount of radiation also leaks through at 1 or 2 millimeters. At much longer wavelengths, the atmosphere again becomes transparent to radio waves from a few millimeters to about 30 meters long, although observations have occasionally been made at wavelengths of about 100 meters through transient "holes" in the earth's ionosphere. The infrared radiation and the shortest radio waves are blocked by molecules of water and carbon dioxide, whereas the longest radio waves are reflected back into space by the charged upper layers of the atmosphere, the ionosphere. The diagram illustrates quite clearly how severe have been the handicaps under which astronomers have been working, especially since the radio window has been used effectively only during the past 15 years.

From knowledge of the composition of the earth's atmosphere and from laboratory experiments on the absorbing power of gases, it is possible to calculate with reasonable precision the altitudes at which the atmosphere becomes transparent to radiation of various wavelengths. The results of one such calculation are shown in figure 2. The curve shown there gives the altitude at which the atmosphere becomes 50 percent transparent for each wavelength of the ultraviolet spectrum. For wavelengths greater than about 2,200 Å., the radiation is absorbed by ozone concentrated mainly in a layer between heights of about 10 to 40 kilometers. From 2,200 Å. to 900 Å. the absorption is caused by oxygen and nitrogen molecules, primarily the former. The reason for the plateau in the curve between 1,400 Å. and 1,800 Å. is that, at about 100 kilometers or a little higher, the oxygen molecules have broken apart into their constituent atoms and hence no longer can absorb radiation at these wavelengths. The dip in the curve at 1,200 Å. is a fortunate circumstance, since it coincides almost exactly with the position of the Lyman- α line of hydrogen, which is strongly emitted by the sun and probably also by most other stars. At altitudes greater than 100 kilometers, radiation is predominantly absorbed by atoms of oxygen and nitrogen which present a solid wall for wavelengths between 200 and 900 Å. At the very shortest wavelengths, X-rays are also screened by atomic oxygen and nitrogen, although they penetrate to relatively low altitudes. The calculations suggest that observations from a height of about 50 kilometers would extend the solar spectrum to 2,200 Å.; at 100 kilometers altitude, the ultraviolet limit would be about 1,100 Å.;

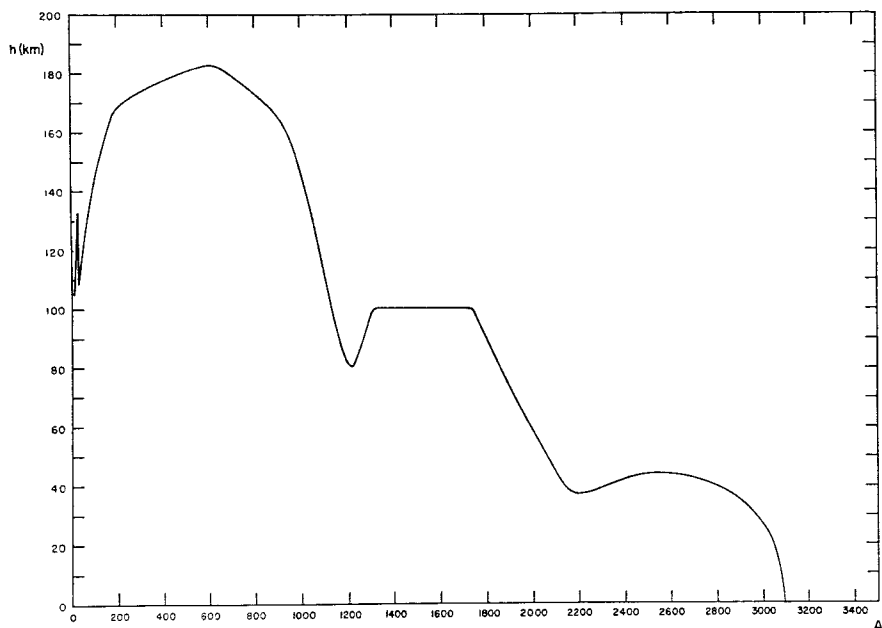


FIGURE 2.—Transparency of the earth's atmosphere to ultraviolet radiation. The curve gives the altitude in kilometers at which the intensity of extraterrestrial radiation is reduced by a factor of 2 at each wavelength.

and with increasing altitude, the short X-rays would begin to come into view. However, the radiation in the 300 to 1,000 Å. band would only be detectable at very great altitudes on the order of about 200 kilometers.

The expectations have largely been confirmed by developments of the past 10 or 12 years, thanks to the introduction of high-altitude rockets as a tool for astronomy. Shortly after the close of World War II, the United States initiated a program of scientific experimentation with a substantial number of V-2 rockets at the White Sands Proving Grounds. From the first, the observation of solar ultraviolet radiation received very high priority, together with cosmic-ray experiments and those concerned with the measurement of pressures and temperatures in the high atmosphere. The first notable success was achieved by a group of scientists at the Naval Research Laboratory, headed by R. N. Tousey, who were successful in photographing the ultraviolet solar spectrum at a series of altitudes up to 55 kilometers. The flight was made on October 10, 1946, and the results obtained are shown in plate 1. This series of photographs represents one of the great achievements in the history of observational astronomy, comparable in importance with the first map of the solar spectrum by Fraunhofer in 1814, with the invention of the spectroheliograph by Hale in 1891, and the coronagraph by

Lyot in 1930. The series of spectra show that the ozone layer begins to be penetrated at a height of 8 kilometers, that the penetration is accelerated at higher altitudes, and that it is complete at 55 kilometers. Many subsequent flights to heights greater than 200 kilometers by the NRL group and by Rense and his collaborators at the University of Colorado have further lengthened the solar spectrum by photography to below 100 Å. The emission of X-rays from the sun has also been studied, chiefly by Friedman and his associates, also at the Naval Research Laboratory, and their observations have been an important feature of the program of the IGY. After depletion of the supply of German V-2 rockets, the program has been continued with Viking and Aerobee rockets of U.S. manufacture, which have been launched both from the ground and from balloons in a combination called the Rockoon.

In spite of the very many great achievements which have been accomplished with rockets, the technique suffers from serious limitations, the most important of which is the very short space of time—a few minutes at the most—during which the rocket is at the top of its trajectory and observations are possible. It has been clear for some time that these limitations could be removed if it were possible to place a large rocket into a stable orbit high above the earth—in other words, to transform the rocket into an artificial satellite of the earth. In this way, the age-old dream could be realized of a laboratory or observatory in space from which the astronomer would have an unobstructed view of the universe. The first indication that this dream might become a reality was given by the spectacular advances in rocketry in Germany during World War II. As early as 1946, feasibility studies in this country had demonstrated the practicability of artificial satellites with then-existing rocket technology, although the cost would have been comparable to that of the Manhattan Project for the development of the atomic bomb. However, these studies were not known to astronomers generally, and even when, in 1955, both the United States and the Soviet Union announced their plans to launch artificial satellites as activities of the IGY, the small sizes of the satellites that were announced made it appear that the astronomical applications would be extremely limited and highly specialized for many years to come.

The news that the Soviet Union had succeeded, on October 4, 1957, in launching an earth satellite with an instrument payload of 184 pounds came as a surprise to most astronomers, who had no knowledge that such large payloads were feasible. The first shock of surprise was soon compounded when the much heavier second and third sputniks were placed in orbit.

However, the shock has now worn off and has been replaced by eager anticipation of the consequences for astronomy of artificial

satellites that can carry several thousand pounds of scientific equipment into orbits hundreds of miles above the surface of the earth. It now appears certain that as a result of the developments in rocket technology, astronomy has entered a new era which promises to be the most exciting in its history. As Otto Struve so aptly put it in a message to the Tenth General Assembly of the International Astronomical Union recently held in Moscow: "Because of this event [the successful launching of the first sputnik] the year 1957 will be remembered in the history of astronomical exploration as the year 1492 is remembered in the history of geographical exploration."

The way is now open for attack on some of the most fundamental problems of astrophysics. Furthermore, the possibility of creating also artificial planets and artificial satellites of planets other than the earth has very important implications for celestial mechanics. Time does not permit the listing of the dozens of fresh and exciting satellite experiments that can be visualized by any competent astronomer. Instead, since the Arthur Lectures are devoted to the sun, I shall confine my attention to this, the most important star in the sky.

Most astronomers would agree that at present the sun should have the highest priority for investigation from satellites. The sun is such an intense source of radiation that instrumental problems are minimized. Further, the influence of the sun upon the earth makes its investigation of very great interest to geophysicists and meteorologists as well as to astronomers. Finally, the sun has been so thoroughly observed from the ground for several centuries that the goals of satellite research are already very clearly defined.

Radiation from the sun takes the form of both photons and particles. From the standpoint of photon radiation, the most important beginning project to be undertaken is the exploration of the complete X-ray and ultraviolet solar spectrum. The spectrum has been photographed from a rocket by Rense to an ultraviolet limit of about 80 Å., from an altitude of over 200 kilometers. The spectrum down to 300 Å. also has been recorded by photoelectric scanning by J. Hinteregger of the Air Force Cambridge Research Center. An exceptionally beautiful spectrogram, obtained by the NRL on March 13, 1959, and covering the region from 500 to 1,800 Å., is shown in plate 2. It can be seen that the continuous spectrum crossed by dark lines, which is characteristic of the solar radiation at longer wavelengths, terminates at about 1,600 Å., and that thereafter the spectrum consists entirely of bright emission lines. By far the brightest line in this region is Lyman- α of neutral hydrogen at 1,216 Å., but other lines arising from neutral and ionized atoms of carbon, nitrogen, oxygen, helium, iron, and silicon are also present. Especially noteworthy are the bright lines of neutral helium at 584 Å., and of nine-times

ionized magnesium at 625 Å. Now the continuous spectrum with its dark lines is radiated by the visible surface of the sun, the so-called *photosphere*, where the temperature is in the neighborhood of 6,000°. As predicted by the well-known laws of black-body radiation, gases at such a relatively low temperature give off very little ultraviolet radiation, and hence the continuous spectrum ceases to be conspicuous at 1,600 Å. However, the layers above the photosphere are very much hotter. At a height of about 50,000 kilometers above the photosphere, in the region of the lower corona, the temperature has already risen to about a million degrees. Between the photosphere and the corona lies the *chromosphere*, the transition region in which the temperature rises precipitously from 6,000° to a million degrees. Through the chromosphere are propagated the hydromagnetic waves that originate in the layers below and must supply the energy to maintain the corona at its very high temperature. The mechanism by which the energy is transferred is not well understood and forms one of the most pressing problems of solar physics. The solution of this problem will come from the study of the spectrum of the chromosphere, particularly the ultraviolet spectrum. The significance of the spectrum shown in the plate is that the bright emission lines (with the exception of the magnesium line at 625 Å., which probably is radiated by the hot corona) do, in fact, originate in the chromosphere. Furthermore, since the temperature is increasing very steeply with height in the chromosphere, lines of high excitation will come from the higher levels. Thus, by exploration of the ultraviolet emission spectrum of the sun the physical state of the chromosphere can be probed through its entire thickness.

Friedman and his collaborators at the Naval Research Laboratory have also, by means of photon counters, recorded the emission of X-rays in the band from about 5 to 150 Å. Most of the emission in this region of the spectrum comes from the highly stripped atoms that prevail at the million-degree temperatures found in the corona. Because the X-ray emission from the sun is expected to be highly variable and extremely sensitive to solar activity (see below) its systematic observation from satellites will be of the greatest importance.

One of the most important activities of the International Geophysical Year has been the continuous monitoring of the sun from a network of stations all around the earth. The purpose of this patrol has been to obtain a complete record of solar activity, or transient disturbances in the solar atmosphere, because of the effect of such solar activity upon the earth. The most common of these transient disturbances are the sunspots, which occur in the photosphere and may therefore be seen visually in the telescope or photographed

in white light. The most spectacular disturbances, however, occur higher up in the chromosphere and are normally visible only in the monochromatic radiations emitted by atoms of ionized calcium and hydrogen. These disturbances comprise what is referred to as "solar activity," or "solar phenomena." Solar phenomena are exceedingly diversified and complex, and it is difficult even to give an organized account of them. The more striking among them include (*a*) the sunspots; (*b*) the so-called plages, which are relatively stable formations that usually, but not always, occur near sunspots and appear perhaps 50 to 100 percent brighter than their surroundings; (*c*) the solar flares, the most catastrophic of all events on the sun, which always break out in plage regions; (*d*) the prominences, great clouds of gas which jut out beyond the limb of the sun and are frequently in violent turbulent motion; and (*e*) the dark flocculi and filaments, which are prominences seen in projection against the solar disk. Plate 3 is a photograph of the sun in the monochromatic red line of hydrogen, $H\alpha$, made with a narrow-band filter, and therefore called a *filtrheliogram*. It shows several types of solar activity, including plages, filaments, and three flares.

Except for some types of prominences, solar activity is generally confined to sunspot regions and indeed the level of activity roughly parallels the sunspot cycle. The lifetimes of solar phenomena are highly variable. Some types of activity, e.g., the surge prominences ejected at the limb, and the high-speed dark flocculi that accompany flares, are exceedingly ephemeral, and last but a few minutes. Great flares may persist for several hours, some types of prominences for weeks, and plages and sunspots for months.

The flare phenomenon is probably the most spectacular of all solar events, because of its complexity, its abrupt commencement, its relationship to other solar phenomena, and its often immediate and dramatic impact upon the earth. It is characterized by a sudden increase in the radiation intensity from relatively small areas up to two or three-tenths of a percent of the total area of the solar disk. The enhanced radiation is almost always in the form of bright lines, and only rarely does the intensity of the continuous spectrum increase. After the initial brightening, the excess radiation intensity dies out slowly in times of from one-half to 3 or 4 hours.

The flare is not an isolated phenomenon on the sun in the sense that it often interacts with and is accompanied by other phenomena.

Thus, dark filaments in the vicinity of flares previously quiescent may suddenly become active. High-speed gas clouds are sometimes ejected from flares at several hundred kilometers per second. Bright flares are almost always accompanied by great bursts of radio noise, particularly in the low-frequency band 20–600 megacycles (see fig. 3). The absolute intensity of these radio bursts at the lowest fre-

quencies is sometimes as high as that which would be radiated by a black body at a temperature in excess of 10^{12} degrees. Many flares observed in recent years have also given rise to rather extraordinary increases in the intensity of cosmic rays from the sun while even rather modest flares can produce sharp bursts of gamma radiation, as have been observed by Winckler and his associates at the University of Minnesota. Solar flares are clearly tremendously energetic phenomena and hence the explanation of their origin and physical nature is one of the fundamental problems of solar physics.

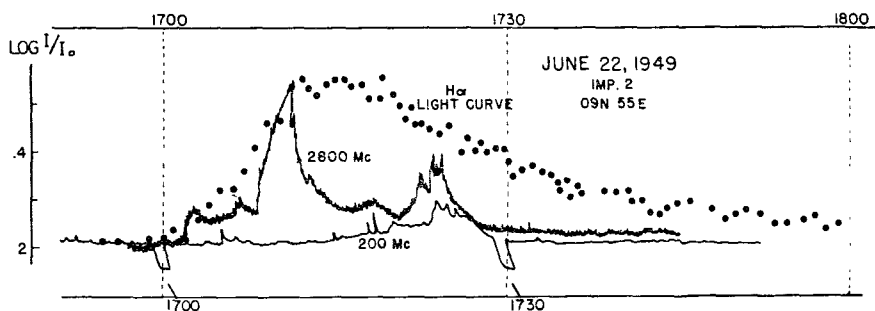


FIGURE 3.—Comparison of $H\alpha$ flare light curve (McMath-Hulbert Observatory) and concomitant 2800 Mc/s and 200 Mc/s solar radiation. The two radio-frequency records were recorded at N.R.C. (Ottawa) and Cornell University, respectively.

Solar activity initiates various events on the earth, chiefly in the upper atmosphere, and hence its study has very important practical consequences for the human race. These events fall into two categories: (1) sudden ionospheric disturbances (SID's), which begin almost immediately upon the onset of a flare and must therefore be caused by radiation from the flare; and (2) geomagnetic storms and displays of northern lights which start about 1 day later and hence must be triggered off by high-speed particles.

Sudden ionospheric disturbances are caused by increases in the degree of ionization of the upper atmosphere in the height range 50–100 kilometers, as a consequence of increased ultraviolet emission from the regions of solar flares. The SID's are manifested in a variety of ways, the most dramatic of which is the sudden fadeout of shortwave radio communications on the earth, in the band 1.5–30 megacycles. An example of such a fadeout in the 5-megacycle signal from station WWV, as received at Cornell University, is shown in figure 4, in relation to the $H\alpha$ light curve of a flare. The lower frequencies are most strongly affected, although at much lower frequencies (about 50 kc.) the transmission is actually improved. The fadeouts may last for a few minutes or for as long as 8 hours, and hence can cause serious dislocation to an important phase of everyday life. The fadeouts can frequently but not always be predicted in advance by observation of the sun in the $H\alpha$ line of hydrogen.

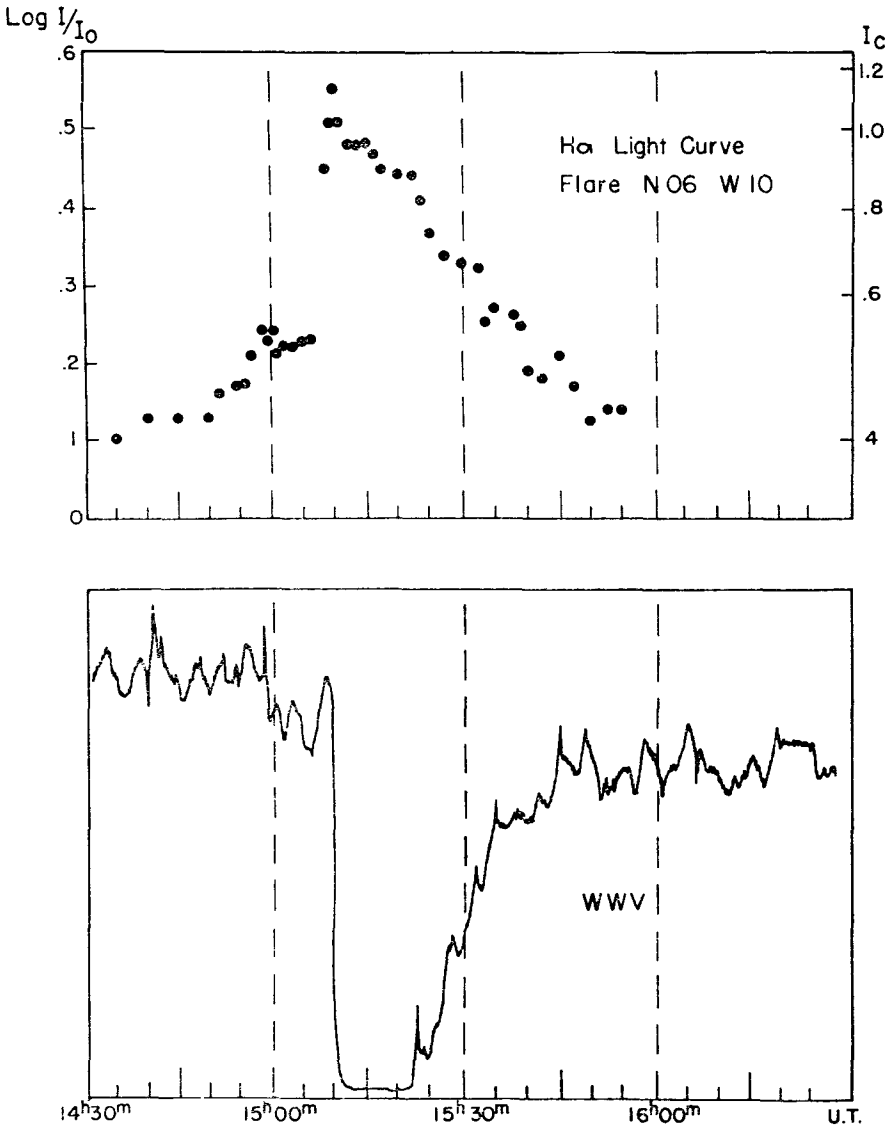
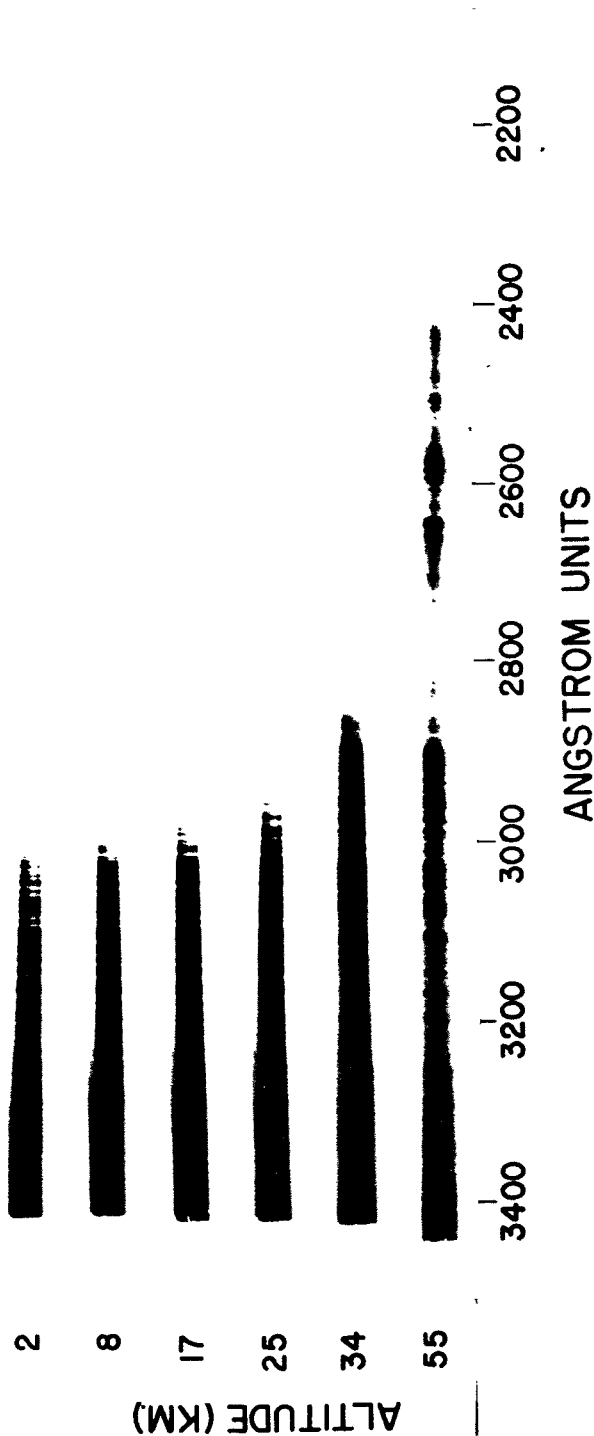
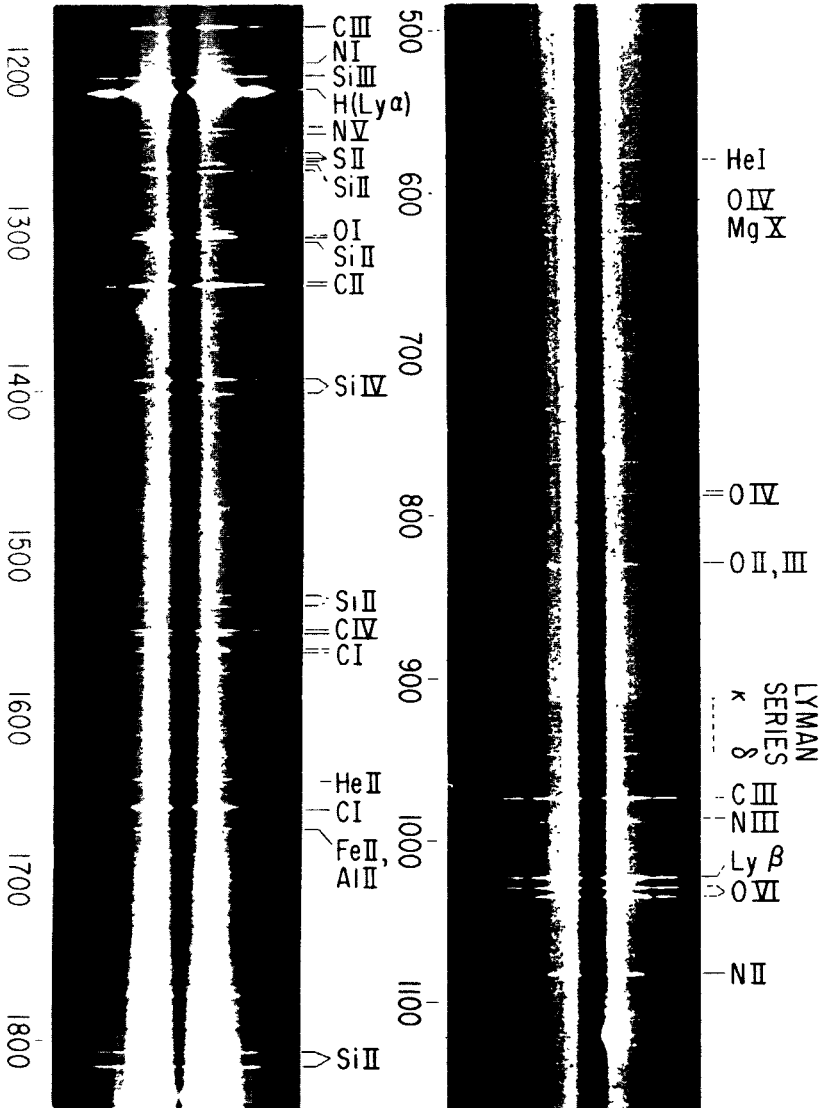


FIGURE 4.—Comparison of H α flare light curve (McMath-Hulbert Observatory) and concomitant short-wave fade, 5 MC, WWV (Cornell), Sept. 15, 1951.

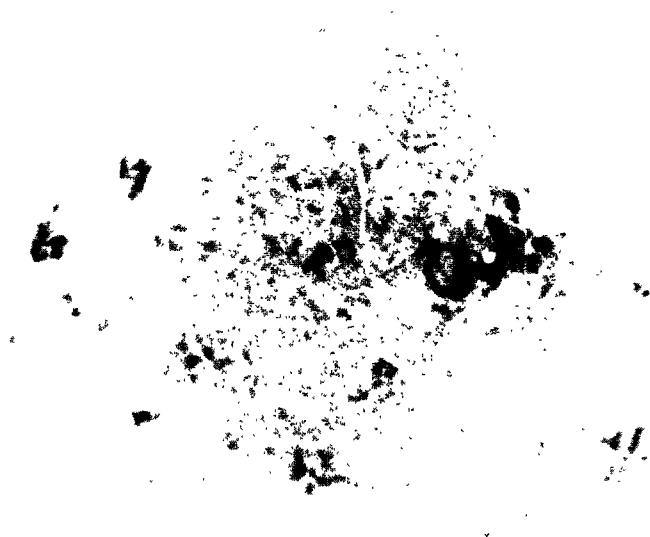
The reason that the predictions are not always accurate is that the visible radiation from the sun does not by itself produce terrestrial events, which are caused by the increased flux of ultraviolet radiation and particles that may accompany the increases in visible light. Unfortunately, the mechanism of the emission of radiation by solar flares is very poorly understood and we cannot at present predict their ultraviolet radiations from observation of the visible light. To com-



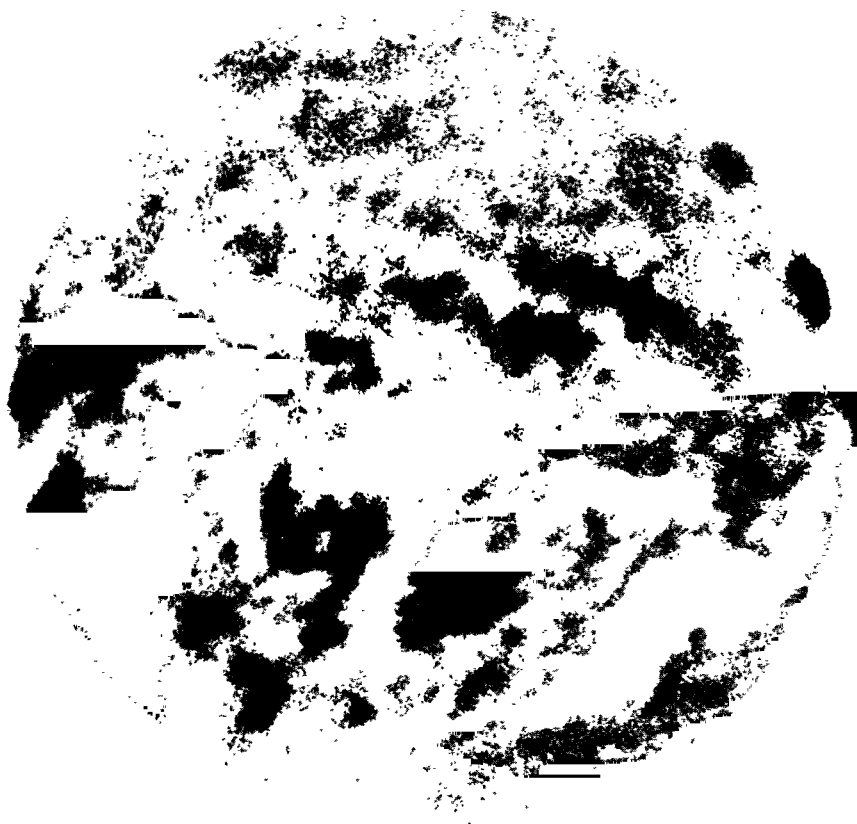
The first solar spectra recorded above the ozone layer. Photographed from a V-2 rocket on October 10, 1946, by the U.S. Naval Research Laboratory.



Ultraviolet spectrum of the sun. Photographed on March 13, 1959, from a Naval Research Laboratory Aerobee rocket, which rose to a height of nearly 200 kilometers. Experiment designed by J. D. Purcell, D. M. Packer, W. D. Hunter, and Richard Tousey.



H α filterheliogram showing filaments, plages, and three flares, 1959, June 18^d11^h44^m U. T.
Flare, importance 3, N17 W13, near maximum; importance 2, N06 E60, past maximum,
importance 1, N19 E47, near maximum (North is at the top, east is at the left) — McMath-
Hulbert Observatory of the University of Michigan.



Solar photograph in the ultraviolet radiation of Lyman- α of hydrogen. Obtained from a Naval Research Laboratory rocket nearly 200 kilometers high on March 13, 1959.

prehend the physical nature of flares and to understand the causes of disturbances to the earth's atmosphere, it is necessary to observe directly the ultraviolet radiation that is now screened from observation on the ground by the earth's atmosphere. The ultraviolet radiation responsible for ionospheric disturbances has, as a result of rocket investigations, been narrowed to a choice between the so-called Lyman- α line of hydrogen, which falls at 1216 A., and soft X-rays of wavelength between 5 and 10 A., although the most recent evidence favors the X-rays.

To resolve the question as to whether the Lyman- α radiation is directly responsible for sudden ionospheric disturbances, it would be sufficient to monitor continuously the total flux of the radiation from the whole solar disk that strikes the top of the earth's atmosphere. Observations of this type have been made during short-time intervals from rockets, but continuous surveillance for extended periods from satellites is an absolute necessity. However, such observations can yield little information concerning the origin and basic physics of the flare phenomenon and its interactions with other related solar activity. The integrated flux observations are also not suitable as a basis for the refined prediction of sudden ionospheric disturbances. For these broader purposes we require monochromatic photographs of the sun in the radiation of Lyman- α , similar to and concurrent with those now being obtained in the red $H\alpha$ line from the ground. The first detailed photograph of this type was obtained by Tousey and associates at the Naval Research Laboratory from an Aerobee rocket on March 13, 1959 (see pl. 4).

Eventually, simultaneous photographs should also be obtained in the ultraviolet lines of other elements in addition to Lyman- α of neutral hydrogen. The most significant lines for this purpose would be those of He I at 584 A. and of He II at 304 A. An interesting byproduct of this program would be the light it would cast upon the detailed structure of the chromosphere, a subject about which there is considerable controversy at present. Thus, there is much evidence that the chromosphere is not homogeneous and that it consists of heterogeneous hot and cold columns with widely differing temperatures ranging from perhaps 5,000° to 50,000°. The high-excitation helium lines seem to be produced in the hot regions, whereas the radiation in low excitation lines defines the cool regions. Comparison of monochromatic photographs made in the different lines might reveal the detailed character of the temperature fluctuations.

A most valuable byproduct of the solar observations would be the detailed information they could provide on the earth's upper atmosphere. About 12 years ago, and even prior to the first successful

rocket photograph of the ultraviolet solar spectrum, Dr. Lyman Spitzer pointed out that, as seen from a satellite, the sun rises and sets at frequent intervals. At these times, the sun's rays would have to traverse the upper atmosphere at different heights before reaching the satellite and would be partially absorbed. Measurement of the changes in the intensity of the spectrum with time would provide a very sensitive determination of the densities of the different types of atoms in the earth's upper atmosphere. It is now known that the ultraviolet spectrum of the sun contains emission lines of oxygen, nitrogen, and hydrogen, and that these lines are absorbed by the same kinds of atoms in the earth's atmosphere. Now the total density of the upper atmosphere can be derived from the changes in the orbit of a satellite caused by frictional drag. If the individual particle densities are also known from spectroscopic measurements, it would be possible to calculate the change of temperature with height at great altitudes and so to answer the question as to the extent of the thermosphere. This is the region above the mesopause in which the temperature increases with height from about 200° Kelvin at 100 kilometers to about 1,100° Kelvin at 300 kilometers. It is not known whether, above 300 kilometers, the atmosphere becomes isothermal, or whether, as Chapman suggests, the temperature continues to rise until the earth's atmosphere merges with the very hot gas of the solar corona at a distance of several earth radii. The possible detection of hydrogen and the measurement of its density at great altitudes would be of particular interest. This could be accomplished by monitoring the intensity of the solar Lyman- α line.

The arrival of solar-ejected particles, chiefly protons and electrons, at the earth is evidenced by their trapping in the Van Allen radiation belts, by the occurrence of magnetic storms and auroral displays, and by the observation of enhanced cosmic-ray intensity following solar flares. During 1959, physicists at the University of Minnesota, led by Ney and Winckler, found, by measurements from balloons, that the earth is being bombarded by bursts of low-energy cosmic rays with a frequency and intensity far greater than had been known or expected. The solar origin of these bursts seems undisputed. At the same time, evidence for the ejection of particles from the sun is best adduced from the observation of bursts of radio noise at very low frequencies. J. P. Wild in Australia has shown that many great solar flares are accompanied by bursts of radio emission which appear first at the higher frequencies, greater than about 200 megacycles, and then drift progressively toward the lower frequencies. Wild has interpreted these bursts as arising from corpuscular streams ejected from the region of solar flares at very high speeds up to 100,000 kilometers per second. The high frequencies come from

low levels in the atmosphere and the lower frequencies from the higher levels as the stream of charged particles moves outward. However, some radio bursts are associated with geomagnetic disturbances while others are not, which suggests that some of the streams do not have enough energy to penetrate the solar atmosphere. To determine which streams do, in fact, escape from the sun, it is necessary to make observations at very low frequencies down to 1 megacycle or less. Unfortunately, radiation at these frequencies cannot penetrate the earth's atmosphere because it is reflected back into space by the ionosphere. Hence, it would be extremely important, as proposed by F. T. Haddock, to make observations over the frequency band from 1 megacycle to 30 megacycles from above the atmosphere. The observation of these radiofrequencies might also make possible, as an interesting byproduct, the measurement of the decrease of electron density in the column of interplanetary space between the sun and the earth.

During the period that has elapsed since this lecture was given the National Aeronautics and Space Administration has announced plans for the development of orbiting astronomical observatories in co-operation with six observatory teams. The plans include provision for both solar and stellar orbiting telescopes. Design studies preliminary to the construction of apparatus for the solar observations outlined above are in progress at the University of Michigan, while other plans are being generated at Princeton University, at the Universities of Rochester and Wisconsin, at the Smithsonian Astrophysical Observatory, and at the Kitt Peak National Observatory. These efforts are in addition to the ongoing programs of extraterrestrial observation at the Naval Research Laboratory and at the University of Colorado.

It is expected that instrumental payloads of about 2,500 pounds will be sent into orbit 500 miles above the earth. Much in the way of laboratory experimentation will be required to insure that the satellite and instrumentation will withstand the severe accelerations and vibrations during the launching operation, and also to make sure that the systems envisaged for the stabilization and pointing control system and for the recording, storage, and transmission of the data will indeed function correctly. However, none of the foreseeable problems appears to be insurmountable engineering-wise, and there can be little doubt that a bright future awaits astronomers as they enter this most exciting period in history.

Solar Radio Astronomy¹

By ALAN MAXWELL

*Radio Astronomy Station of Harvard College Observatory
Fort Davis, Tex.*

[With 2 plates]

THE BEGINNINGS of radio astronomy are to be found in the work of James Clerk Maxwell, Faraday, and Hertz. A few years after Hertz's pioneer work on radio waves, astronomers were speculating whether the solar corona could be the source of electromagnetic disturbances and emit radio waves. About 1900 Sir Oliver Lodge attempted to observe such waves, but this attempt was doomed to failure by the inadequacy of the available radio techniques. Subsequently, the idea of searching for extraterrestrial radio emissions was abandoned, and for many years astronomers showed no further interest in the matter.

In 1932, Jansky, investigating atmospherics at a wavelength of 15 meters, found that the noise which his antenna system picked up showed a variation whose periodicity was not exactly 24 hours, but was 23 hours 56 minutes, corresponding to the period of the earth's rotation relative to the stars. Jansky concluded that this radio noise came from the Milky Way, and suggested that the radio waves were being generated either in the stars or in interstellar space. This work should have been of peculiar interest to astronomers, but it received little attention. It was followed up by one or two people, notably by Reber, but it was not until the years immediately following the Second World War that the tremendous astronomical significance of this early discovery was realized.

In 1948, Bolton and Stanley, in Australia, announced that they had discovered an intense source of radio emission whose angular diameter in the sky was less than 8 minutes of arc, and whose position lay in the constellation of Cygnus. Shortly afterward, Ryle and Smith at Cambridge, England, discovered a second, even more intense, radio

¹ The 26th annual James Arthur lecture on the sun, given under the auspices of the Smithsonian Institution on Oct. 15, 1959.

source in the constellation of Cassiopeia. Since these pioneer discoveries, many radio sources have been cataloged. A number of these coincide in position with outstanding objects in the sky: some with supernovae, others with interacting galaxies, nebulous condensations, and so on. It is, however, one of the outstanding enigmas of radio astronomy that the great proportion of these radio sources defy optical identification. This has led to a great deal of speculation, some of it premature, concerning the nature of the radio sources, not to mention the nature of the universe in which we live. It is clear, however, that the radio astronomer's universe bears a marked similarity to the optical astronomer's universe.

The radiations from outer space known as "light" cover a very small section of the electromagnetic spectrum—one octave, to be precise. By contrast, the radio waves reaching the earth from outer space cover approximately 12 octaves of the spectrum. For receiving equipment on the earth, the boundary to observations at short wavelengths is set at 0.5 cm. by the absorption effects of oxygen and water vapor in the terrestrial atmosphere. At long wavelengths, greater than about 30 m., the radio waves are reflected back into outer space by the terrestrial ionosphere. The incoming radio signals do not have the properties of speech or music: they have the mathematical form and audible characteristics of random noise.

The basic instruments of radio astronomy comprise a directive antenna, which is often a paraboloid of large aperture, and a sensitive radio receiver provided with means for accurate calibration. In radio telescopes of paraboloidal design, the focus is occupied not by a photographic plate, as in optical astronomy, but by a simple primary antenna system, which passes the radio signals along to a radio receiver. Permanent records are generally obtained with pen recorders, or, in some cases, by photographing cathode ray tubes.

One of the great difficulties confronting radio astronomers is that the radio wavelengths, which are of the order of a million times longer than those of light, make the resolving power of radio telescopes greatly inferior to that of optical telescopes. The 250-foot paraboloid at the Jodrell Bank Experimental Station, in England, at its shortest operating wavelength has a resolution which is not so good as that of the human eye. To some extent, it has been possible to develop special antennas for obtaining high directional discrimination. Most of these antennas make use of interference techniques, and are subject to confusion, if the brightness pattern of the part of the sky under examination is complex. In their efforts to achieve improved resolution, radio astronomers have contributed greatly to the development of antennas. One particularly interesting example is a cruciform array developed by Mills, and another is an elaborate periodic array developed by Christiansen.

BACKGROUND RADIATION FROM THE SUN

The radio emissions from the sun, the only star from which radio waves have as yet been detected, consist of a background thermal emission from the solar atmosphere, and transitory disturbances, sometimes of great intensity, which originate in localized active areas. The first successful observations of the background radiation were carried out in 1942 by Southworth, who worked in the United States with equipment operating at wavelengths between 3 and 10 cm. Since that time a considerable amount of effort and ingenuity has been devoted to determining the parameters of the background radiation, which gives us direct information about the distribution of temperature and electron density in the solar atmosphere. A great deal of this work was done with interferometers of variable spacing, and many of the observations were carried out during the recent sunspot minimum, from 1952 through 1955. The experimental work has substantially confirmed the radio models of the solar atmosphere proposed by Ginzburg, in Russia, in 1946, and independently by Martyn, in Australia, in 1946.

The early observations revealed that radio emissions of different wavelength originate from different levels in the solar atmosphere; the shorter wavelengths from the lower levels (the chromosphere), and the longer wavelengths from the outer regions (the corona). The intensities of these emissions not unexpectedly depend on the temperature of the appropriate emitting level, which is of the order of 20,000 degrees in the chromosphere, and 1 million degrees in the outer corona. The observations also show that at the longer wavelengths the sun has a diameter of about 1 degree, which is twice that of its optical disk.

RADIOHELIOGRAPHS

Despite the small angular size of the sun, it has been possible to determine the precise distribution of brightness over the solar disk at various radio wavelengths. That is, pictures have been obtained showing how the sun would look if our eyes were tuned to radio waves instead of light. One of the most interesting of such experiments has been carried out by Christiansen, who has equipment operating at 21 cm. (not the radio spectral line of hydrogen). Christiansen uses 64 paraboloids, each having a diameter of 19 feet. These are arranged in two rows, north-south and east-west, in the form of a cross. The paraboloids are spaced at 40-foot intervals, so that the overall length of each arm of the cross is 1,240 feet (pl. 1, fig. 1). The signals from the two arms are combined, alternately in phase and out of phase, and the component of the output which alternates in synchronism is recorded. The system has a directional diagram which comprises a grid of points in the sky, and as the earth rotates,

the various points in the grid scan different strips across the sun. In this way a picture of the sun is built up in the manner of a television picture in a period of about half an hour (fig. 1). All 64 paraboloids are turned on equatorial axes to continue pointing at the sun during this time. These radioheliograms may be compared with the well-known optical spectroheliograms taken in $H\alpha$ light. The optical spectroheliograms give a comprehensive picture of the chromosphere, with its prominences, flares, and plages. The radio-

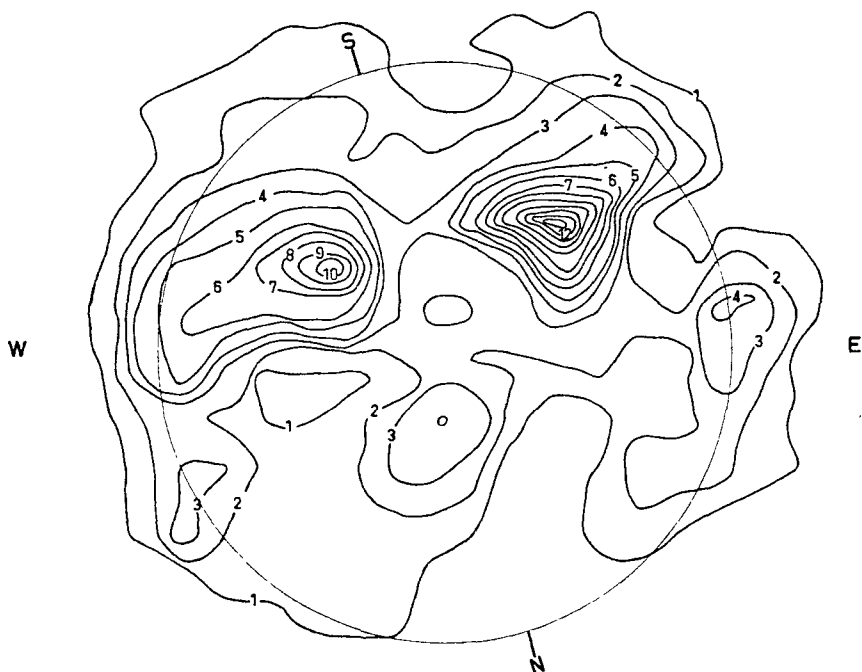


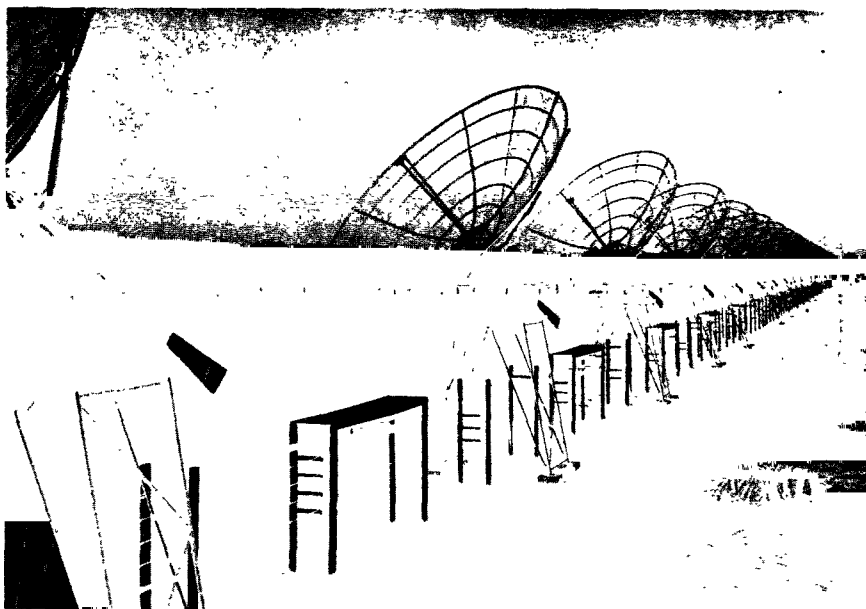
FIGURE 1.—Radioheliogram of the sun at 21 cm. The contour brightness unit is 0.93×10^8 °K. (Diagram courtesy of Dr. W. N. Christiansen, CSIRO Division of Radio-physics, Sydney, Australia.)

heliograms give an indication of the brightness distribution at a height of approximately 50,000 km. They show a close, but not perfect correspondence with the chromospheric plages and sunspots.

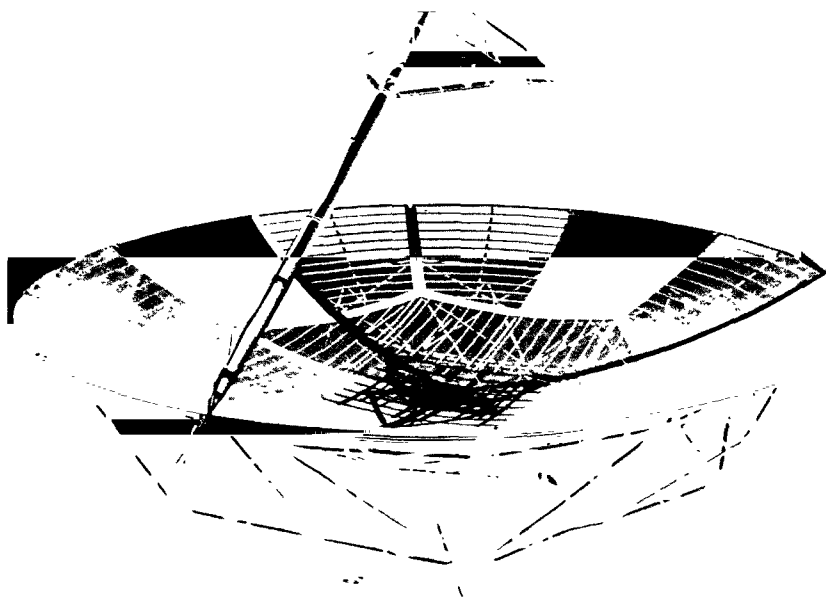
Similar instruments have now been put into operation at 1.8 m. and 3.2 cm. at Meudon, France; 10 cm. at Stanford University; and 88 cm. at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

TRANSIENT RADIO BURSTS FROM THE SUN

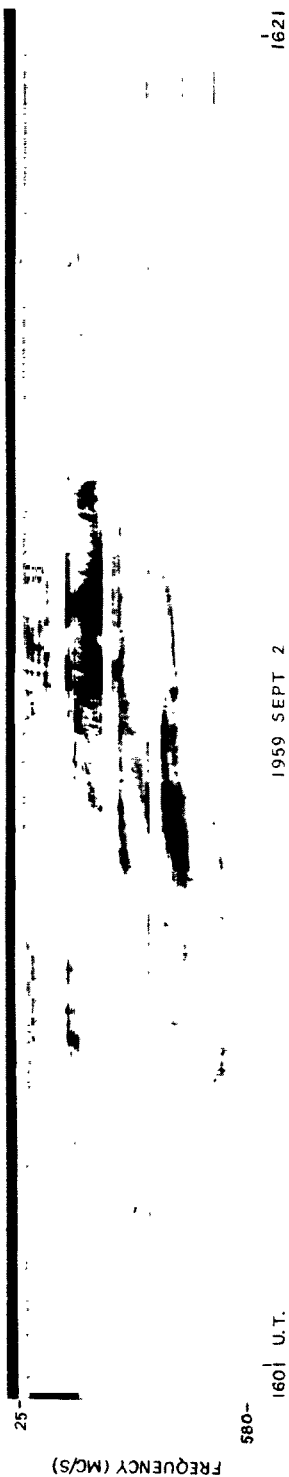
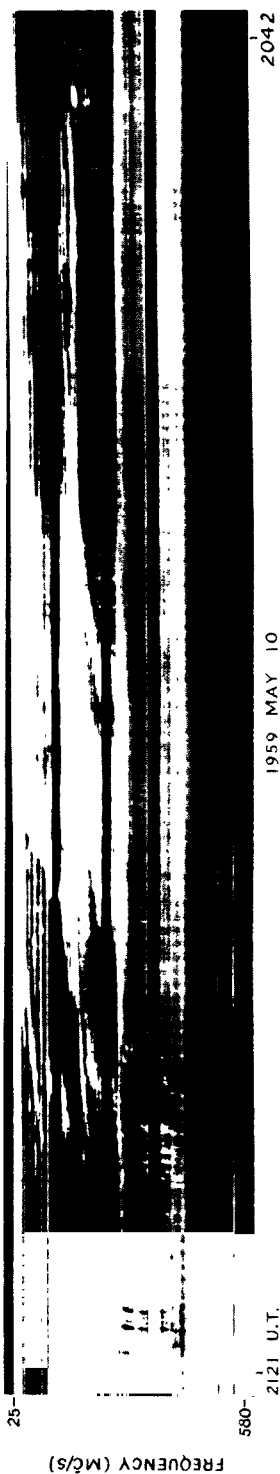
The discovery of intense transient radio bursts from the sun was made accidentally in England during the air battles of World War II. In February 1942, radar operators, watching the skies for enemy aircraft, noticed an unusual form of interference. It was at first



1. One arm of the crossed periodic array used for solar observations at 21 cm. in Sydney.
(Photograph courtesy of CSIRO Division of Radiophysics, Sydney, Australia.)



2. The 28-foot antenna and 4-octave primary feed system used for solar radio observations
at the Harvard Radio Astronomy Station, Fort Davis, Tex.



Sweep frequency records of solar radio bursts on May 10, 1959, and September 2, 1959, taken at the Harvard Radio Astronomy Station, Fort Davis, Tex. These bursts were caused by disturbances moving outward through the solar atmosphere at approximately 1,000 km. per second. Both the bursts were followed approximately 30 hours later by terrestrial magnetic storms.

thought that the radar equipment was being jammed by the enemy, but J. S. Hey, of the British Army Operational Research group, traced the source of the disturbance to the sun. He also noted that the radio emissions from the sun were associated with the presence of sunspots on the solar disk. At the same time, a similar effect was noted on long-range radar systems in operation at Norfolk Island in the South Pacific. The increased noise level in these radars was also traced to solar disturbances.

After World War II these bursts of radio emission from the sun were investigated in considerable detail with fixed-frequency receivers operating at numerous points throughout the whole radio spectrum. It was found that the radio emissions usually came in the form of a storm of bursts, whose intensity level was often 1,000 times the background radiation from the sun. These radio noise storms frequently lasted for several days. At times, generally coincident with the appearance of a great flare on the solar disk, there were outbursts of radio noise in which the intensity of the emissions could increase by a factor of a further thousand or more. Comparison of the records obtained with receivers operating at different wavelengths at the time of such outbursts revealed an interesting effect. The solar radio outburst was first observed with the equipment operating at the shorter wavelengths, while at the longer wavelengths it did not appear until several minutes later. Payne-Scott, Yabsley, and Bolton suggested in 1947 that this striking phenomenon might be caused by the outward passage of a disturbance, traveling at about 1,000 km. per second through the solar atmosphere. As the disturbance traversed the chromosphere it would send out a burst of radio waves in the centimeter band; then, as it continued to travel outward through the solar atmosphere, it would send out radio bursts of successively increasing wavelength.

SWEEP FREQUENCY RECEIVERS

The most convenient manner of studying such solar bursts, which traverse a large part of the radio spectrum, is to use receivers which record emissions from the sun over a wide range of radio wavelengths. The first such instrument was put into operation in Sydney, in 1949, and it covered the band 70–130 Mc./s. It was subsequently extended to cover the range 40–240 Mc./s. This instrument marked a notable advance in solar radio techniques, and the resulting observations greatly simplified the existing complex classification of solar radio phenomena.

In 1956 a similar experiment was put into operation at the Harvard Radio Astronomy Station, in Fort Davis, Tex. The equipment at this station covered a different part of the radio spectrum, was of greater sensitivity, and used a larger antenna. It originally operated over

the band 100–580 Mc./s., but has now been extended to cover nearly six octaves of the electromagnetic spectrum, from 25–580 Mc./s. and from 2,000–4,000 Mc./s. As with the earlier Australian experiments, the Fort Davis equipment uses narrow-band tunable receivers that are repeatedly swept across a wide frequency range. The equipment comprises six separate receivers, since with existing radio techniques it is not possible for one receiver to cover a band of more than one octave. Because of its tremendous frequency range and high sensitivity, it was necessary to place the equipment in a remote section of the United States, to avoid manmade radio interference.

The four very high and ultrahigh frequency receivers at Fort Davis are connected to a complex arrangement of primary antennas at the focus of a 28-foot paraboloid reflector (pl. 1, fig. 2), which tracks the sun daily from sunrise to sunset. The two low-frequency receivers are connected to a fixed array that does not track the sun, but has a broad beam directed along the meridian at the celestial equator, so that the sun can be monitored for the greater part of the day. The equipment has now been in continuous operation from sunrise to sunset for just over 3 years, and an average of 95 percent of the possible observing time has been maintained. This may be compared with optical solar observations which are generally limited by inclement weather to less than 50 percent of the possible observing time.

All six receivers sweep their respective octave bands three times per second, and their outputs are displayed on six cathode ray tubes. The spot displacement on each of these cathode ray tubes is proportional to the instantaneous frequency of the receiver, while the brightness is proportional to the receiver output. The cathode ray tubes are photographed with a 70-mm. camera, in which the film moves continuously at a speed of approximately half an inch per minute. Time marks are photographed onto this film to an accuracy of 1 second. Originally the limit on the intensity range of the observations was set by the film emulsion, which cannot handle signals that differ in intensity by more than 1,000:1. Two years ago, however, the response of the amplifiers in the receivers was "compressed," and in this way it was possible to extend the intensity range to 100,000:1. This is typical of the way in which the inherent flexibility of electronic equipment is used to offset the limitations imposed on a system by its optical, mechanical, or audio sections.

The frequency coordinate on the spectral films may be interpreted in terms of height in the solar atmosphere, according to the model of the solar atmosphere shown in figure 2. As would be expected, the equipment not only monitors the disturbances which occur at a given level in the solar atmosphere, but also gives warning of any disturbances which are moving inward or outward through the solar atmos-

phere. For example, a giant explosion near the solar surface—if at the limb of the sun, it is visible as an eruptive, surge, or spray prominence—will eject intense, fast-traveling shock waves, and jets of fast-moving particles. From the slope of the bursts on the film records (pl. 2), it is possible to deduce that some of these disturbances travel at speeds of approximately 1,000 km. per second. Such disturbances frequently continue traveling out from the sun until they reach the earth, where they give rise to the magnificent spectacle of the aurora

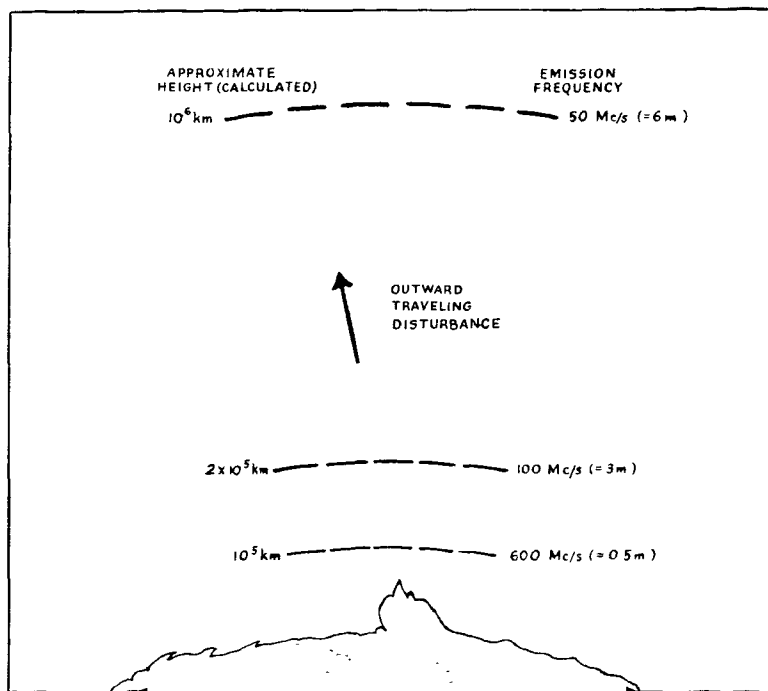


FIGURE 2.—Radio model of the solar atmosphere. A disturbance traveling outward through the solar atmosphere traverses regions of progressively lower electron density and generates radio signals of progressively decreasing frequency. The height figures are approximate.

polaris, and simultaneously disrupt the earth's radio communications. On the average, the Fort Davis equipment has recorded about 30 such bursts per year over the sunspot maximum, and about half of them have been followed by terrestrial disturbances.

Other disturbances travel outward at a velocity of about 100,000 km. per second. These cause very short-lived radio bursts, about 10,000 of which have been recorded every year of the sunspot maximum at Fort Davis. There is at present much speculation concerning the nature of the disturbance which gives rise to these radio bursts: whether it takes the form of a tremendously fast-moving shock wave, or whether it is a stream of particles.

It will be noticed that, until this point, the existence of these disturbances and the measurement of their speed have been inferred from the interpretation of the emitted radio frequencies in terms of an equivalent height in the solar atmosphere. Thus, a rate of change of frequency is interpreted in terms of a rate of change of height, which is the mathematical expression of velocity. Over the past year, these plausible assumptions have been brilliantly confirmed in an experiment which combines both sweep frequency equipment and an interferometer, to give a direct measure of the translational velocity of these disturbances. This work, carried out in Australia by J. P. Wild, shows that these spectacular forms of solar radio bursts are definitely caused by disturbances moving outward through the solar atmosphere with the velocities quoted above.

SOLAR RADIO BURSTS AND LOW-ENERGY COSMIC RAYS

Recent observations, with scintillation and Geiger counters carried in satellites and balloons, have shown that the terrestrial atmosphere is frequently bombarded by solar protons of energies 30–300 Mev., which may be designated low-energy cosmic rays. The solar protons have been detected outside the Van Allen radiation zones, at high magnetic latitudes. Because of their low magnetic rigidity, these particles can penetrate the terrestrial atmosphere only in the vicinity of the magnetic poles, and in these regions they also give rise to ionospheric polar blackouts.

There has been much speculation concerning the origin of the low-energy solar cosmic rays, and their relation to solar radio bursts and flares. Examination of the solar radio data recorded over the past 18 months shows that the low-energy cosmic rays are preceded by radio bursts of an unusual and exciting nature. Among solar radio astronomers these are known as continuum bursts of spectral Type IV. This type of radiation characteristically covers several octaves of the radio spectrum, is generally of great intensity, and often lasts for many hours. It has been suggested that it originates from a synchrotron mechanism (the Schwinger mechanism), in which electrons with relativistic velocities are trapped in orbital motion in a magnetic field. The onset of the synchrotron radiation is generally preceded, about 15 minutes ahead, by a solar flare, usually of importance 3 or 3+. Approximately 1 hour later, solar protons commence bombarding the earth. This sequence of events is now quite clearly established, and it has already occurred five times this year. On May 11 and 12, 1959, the integral flux of protons at the top of the atmosphere increased by a factor of approximately 1,000 over the galactic cosmic ray component, and the composition of the incoming beam was essentially pure hydrogen. This spectacular increase in the proton count was preceded by solar radio outbursts of the continuum type on

May 10 and 11. These great increases in cosmic rays, above the terrestrial atmosphere, may, or may not, constitute an additional hazard for space travel. It is, however, of considerable interest to note that their emission from the sun is detected by solar radio astronomers approximately 1 hour in advance of their arrival at the earth.

CONCLUSION

Over the past decade the information obtained by radio techniques has revolutionized existing theories of the processes that occur in the solar atmosphere. It has also helped elucidate the complicated series of events that originate in the sun and subsequently affect the earth's atmosphere. Early theories advanced to account for thermal radio emissions from the solar atmosphere have now been well substantiated, and some understanding has also been achieved of the nonthermal processes which give rise to intense radio outbursts. Within the next few years we may expect to see a large accumulation of results from the radio helioscopes which are now being put into operation throughout the world, increased efforts to improve the present resolving power of radio instruments, and the extension of sweep frequency observations even further over the radio band.

The New Uses of the Abstract¹

By GEORGE A. W. BOEHM

NEVER BEFORE have so many people applied such abstract mathematics to so great a variety of problems. To meet the demands of industry, technology, and other sciences, mathematicians have had to invent new branches of mathematics and expand old ones. They have built a superstructure of fresh ideas that people trained in the classical branches of the subject would hardly recognize as mathematics at all.

Applied mathematicians have been grappling successfully with the world's problems at a time, curiously enough, when pure mathematicians seem almost to have lost touch with the real world. Mathematics has always been abstract, but pure mathematicians are pushing abstraction to new limits. To them mathematics is an art they pursue for art's sake, and they do not much care whether it will ever have any practical use.

Yet the very abstractness of mathematics makes it useful. By applying its concepts to worldly problems the mathematician can often brush away the obscuring details and reveal simple patterns. Celestial mechanics, for example, enables astronomers to calculate the positions of the planets at any time in the past or future and to predict the comings and goings of comets. Now this ancient and abstruse branch of mathematics has suddenly become impressively practical for calculating orbits of earth satellites.

Even mathematical puzzles may have important applications. Mathematicians are still trying to find a general rule for calculating the number of ways a particle can travel from one corner of a rectangular net to another corner without crossing its own path. When they solve this seemingly simple problem, they will be able to tell chemists something about the buildup of the long-chain molecules of polymers.

Mathematicians who are interested in down-to-earth problems have learned to solve many that were beyond the scope of mathematics only a decade or two ago. They have developed new statistical methods for controlling quality in high-speed industrial mass produc-

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tion. They have laid foundations for Operations Research techniques that businessmen use to schedule production and distribution. They have created an elaborate theory of "information" that enables communications engineers to evaluate precisely telephone, radio, and television circuits. They have grappled with the complexities of human behavior through game theory, which applies to military and business strategy alike. They have analyzed the design of automatic controls for such complicated systems as factory production lines and supersonic aircraft. Now they are ready to solve many problems of space travel, from guidance and navigation to flight dynamics of missiles beyond the earth's atmosphere.

Mathematicians have barely begun to turn their attention to the biological and social sciences, yet these once purely descriptive sciences are already taking on a new flavor of mathematical precision. Biologists are starting to apply information theory to inheritance. Sociologists are using sophisticated modern statistics to control their sampling. The bond between mathematics and the life sciences has been strengthened by the emergence of a whole group of applied mathematics specialties, such as biometrics, psychometrics, and econometrics.

Now that they have electronic computers, mathematicians are solving problems they would not have dared tackle a few years ago. In a matter of minutes they can get an answer that previously would have required months or even years of calculation. In designing computers and programing them to carry out instructions, furthermore, mathematicians have had to develop new techniques. While computers have as yet contributed little to pure mathematical theory, they have been used to test certain relationships among numbers. It now seems possible that a computer someday will discover and prove a brand-new mathematical theorem.

The unprecedented growth of U.S. mathematics, pure and applied, has caused an acute shortage of good mathematicians. Supplying this demand is a knotty problem. Mathematicians need more training than ever before; yet they cannot afford to spend more years in school, for mathematicians are generally most creative when very young. A whole new concept of mathematical education, starting as early as the ninth grade, may offer the only escape from this dilemma.

CONVENIENCE OF THE OUTLANDISH

The applied mathematician must be a creative man. For applied mathematics is more than mere problem solving. Its primary goal is finding new mathematical approaches applicable to a wide range of problems. The same differential equation, for example, may describe the scattering of neutrons by atomic nuclei and the propaga-

tion of radio waves through the ionosphere. The same topological network may be a mathematical model of wires carrying current in an electric circuit and of gossips spreading rumors at a tea party. Because applied mathematics is inextricably tied to the problems it solves, the applied mathematician must be familiar with at least one other field—e.g., aerodynamics, electronics, or genetics.

The pure mathematician judges his work largely by esthetic standards; the applied mathematician is a pragmatist. His job is to make abstract mathematical models of the real world, and if they work, he is satisfied. Often his abstractions are outlandishly far-fetched. He may, for example, consider the sun as a mass concentrated at a point of zero volume, or he may treat it as a perfectly round and homogeneous sphere. Either model is acceptable if it leads to predictions that jibe with experiment and observation.

This matter-of-fact attitude helps to explain the radical changes in the long-established field of probability theory. Italian and French mathematicians broached the subject about three centuries ago to analyze betting odds for dice. Since then philosophers interested in mathematics have been seriously concerned about the nature of a mysterious "agency of chance." Working mathematicians, however, do not worry about the philosophic notion of chance. They consider probability as an abstract and undefined property—much as physicists consider mass or energy. In so doing, mathematicians have extended the techniques of probability theory to many problems that do not obviously involve the element of chance.

Probability today is almost like a branch of geometry. Each outcome of a particular experiment is treated as the location of a point on a line. And each repetition of the experiment is the coordinate of the point in another dimension. The probability of an outcome is a measure very much like the geometric measure of volume. Many problems in probability boil down to a geometric analysis of points scattered throughout a space of many dimensions.

One of the most fertile topics of modern probability theory is the so-called "random walk." A simple illustration is the gambler's ruin problem, in which two men play a game until one of them is bankrupt. If one starts with \$100 and the other with \$200 and they play for \$1 a game, the progress of their gambling can be graphed as a point on a line 300 units (i.e., dollars) long. The point jumps one unit, right or left, each time the game is played, and when it reaches either end of the line, one gambler is broke. The problem is to calculate how long the game is likely to last and what chance each gambler has of winning.

Mathematicians have recently discovered some surprising facts about such games. When both players have unlimited capital and

the game can go on indefinitely, the lead tends not to change hands nearly so often as most people would guess. In a game where both players have an equal chance of winning—such as matching pennies—after 20,000 plays it is about 88 times as likely that the winner has led all the time as that the two players have shared the lead equally. No matter how long the game lasts, it is more likely that one player has led from the beginning than that the lead has changed hands any given number of times.

The random-walk abstraction is applicable to a great many physical situations. Some clearly involve chance—e.g., diffusion of gases, flow of automobile traffic, spread of rumors, progress of epidemic disease. The technique has even been applied to show that after the last glacial period seed-carrying birds must have helped reestablish the oak forests in the northern parts of the British Isles. But some modern random-walk problems have no obvious connection with chance. In a complicated electrical network, for example, if the voltages at the terminals are fixed, the voltages at various points inside the circuit can be calculated by treating the whole circuit as a sort of two-dimensional gambler's ruin game.

RISK VERSUS GAIN

Mathematical statistics, the principal offshoot of probability theory, is changing just as radically as probability theory itself. Classical statistics has acted mainly as a tribunal, warning users against drawing risky conclusions. The judgments as handed down are always somewhat equivocal, such as: "It is 98 percent certain that drug A is at least twice as potent as drug B." But what if drug A is actually only half as potent? Classical statistics admits this possibility, but does not evaluate the consequences. Modern statisticians have gone a step farther with a new set of ideas known collectively as decision theory. "We now try to provide a guide to actions that must be taken under conditions of uncertainty," explains Herbert Robbins of Columbia. "The aim is to minimize the loss due to our ignorance of the true state of nature. In fact, from the viewpoint of game theory, statistical inference becomes the best strategy for playing the game called science."

The new approach is illustrated by the following example. A philanthropist offers to flip a coin once and let you call "heads" or "tails." If you guess right, he will pay you \$100. You notice the coin is so badly bent and battered that it is much more likely to land on one side than the other. But you cannot decide which side the coin favors. The philanthropist is willing to let you test the coin with trial flips, but he insists you pay him \$1 for each experiment. How many trial flips should you buy before you make up your mind? The answer, of course, depends on how the trials turn out. If the coin

lands heads up the first five times, you might conclude that it is almost certainly biased in favor of heads. But if you get three heads and two tails, you would certainly ask to experiment further.

Industry faces this kind of problem regularly. A manufacturer with a new product tests it before deciding whether to put it on the market. The more he tests, the surer he will be that his decision will be right. But tests cost money, and they take time. Now modern statistics can help him balance risk against gain and decide how long to continue testing. It can also help him design and carry out experiments. New methods involving a great deal of multidimensional geometry can point out how products and industrial processes can be improved. A statistician can often apply these methods to tune up a full-scale industrial plant without interrupting production. (For an example, see the diagrams, figs. 1 and 2.)

Classical statistics has been extended in another way. One of the latest developments is "nonparametric inference," a way of drawing conclusions about things that can be sorted according to size, longevity, dollar value, or any other graduated quality. What matters is the size of the statistical sample and the ranking of any particular object in that sample. It is not actually necessary to measure any of the objects, so long as they can be compared. It is possible to say, for instance, that if the sample consists of 473 objects, it is 99 percent certain that only 1 percent of all objects of this sort will be larger than the largest object in the sample. It makes no difference what the objects are—people, automobiles, ears of corn, or numbers drawn out of a hat. And the statement is still true if instead of largeness you consider smallness, intelligence, cruising speed, or any other relevant quality.

In practical application, nonparametric inference is being used to test batches of light bulbs. By burning a sample of 63 bulbs, for example, the manufacturer can conclude that 90 percent of all the bulbs in the batch will almost certainly (99 chances out of 100) have a longer life than the second bulb to burn out during the test.

One of the most fascinating recent developments in applied mathematics is game theory, another offshoot of probability theory (see "A Theory of Strategy," *Fortune*, June 1949). From a mathematical viewpoint, game theory is not particularly abstruse; many mathematicians, indeed, consider it shallow. But it is exciting because it has given mathematicians an analytic approach to human behavior.

Game theory is basically a mathematical description of competition among people or such groups of people as armies, corporations, or bridge partnerships. In theory, the players know all the possible outcomes of the competition and have a firm idea of what each outcome is worth to them. They are aware of all their possible strategies and those of their opponents. And invariably they behave

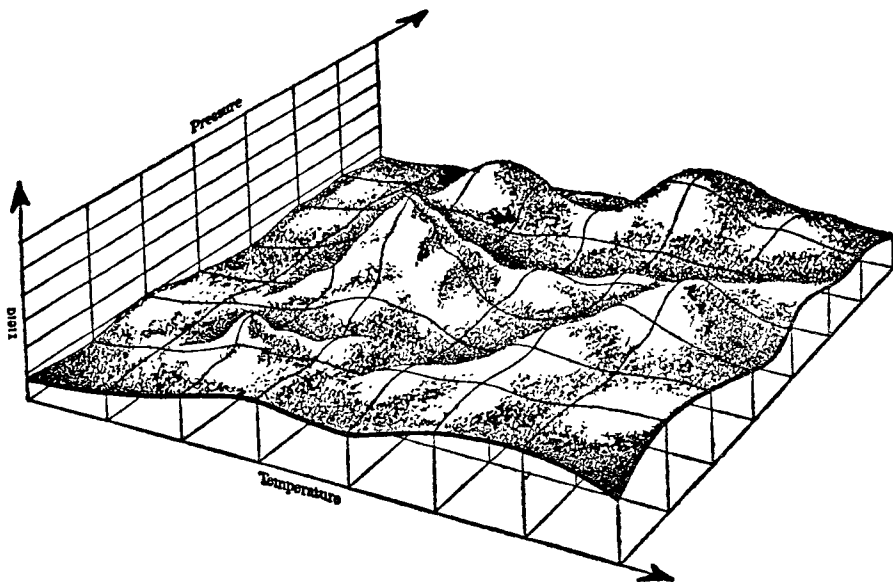


FIGURE 1

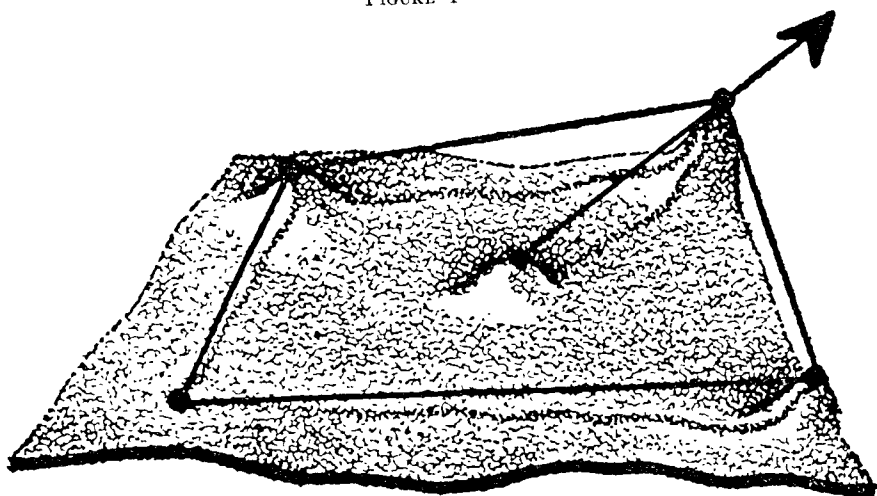


FIGURE 2

FIGURES 1 and 2.—Geometry helps statisticians improve industrial products and processes, such as the hypothetical chemical process shown in the diagram in figure 1. Like a great many processes, it is hard to perfect because it responds in a very irregular way to changes in temperature and pressure. The statistician doesn't have to know any chemical theory to find out what temperature and pressure settings give the maximum yield—represented by the highest point on the "response surface." Rather, he approaches the problem like a blind man trying to find the highest peak in an unfamiliar country. The drawing in figure 2 illustrates his procedure. He starts with arbitrary settings and varies them slightly so that he can determine yields at the corners of a small square on the surface. If one corner is significantly higher than the others, he starts over again at that point and varies the settings to explore another small square. Successive steps lead him higher and higher. As the diagram in figure 1 makes evident, he should be misled by several topographic features—e.g., the small peak in the foreground, the ridge at the right, or the crest of the pass between the twin peaks in the rear. Such a response surface could just as well represent engine performance as fuel and carburetor adjustment vary, or any other measurable quantity. When there are many variables to consider, the geometry becomes more complicated, because the surface has as many dimensions as there are independent variables.

“rationally” (though mathematicians are not sure just how to define “rational” behavior). Obviously, game theory represents a high degree of abstraction; people are never so purposeful and well informed, even in as circumscribed a competition as a game of chess. Yet the abstraction of man is valid to the extent that game theory is proving useful in analyzing business and military situations.

When it was first developed in the twenties, chiefly by Émile Borel in France and John von Neumann in Germany, game theory was limited to the simplest forms of competition. As late as 1944 the definitive book on the subject (“Theory of Games and Economic Behavior,” by Von Neumann and Princeton economist Oskar Morgenstern) drew many of its illustrative examples from a form of one-card poker with limited betting between two people. Now, however, the strategies of two-person, zero-sum games (in which one player gains what his opponent loses) have been quite thoroughly analyzed. And game theorists have pushed on to more complex types of competition, which are generally more true to life.

Early game theory left much to be desired when it assumed that every plan should be designed for play against an allwise opponent who would find out the strategy and adopt his own most effective counterstrategy. In military terms, this amounted to the assumption that the enemy’s intelligence service was infallible. The game-theory solution was a randomly mixed strategy—one in which each move would be dictated by chance, say the roll of dice, so that the enemy could not possibly anticipate it. (For much the same reason the United States Armed Forces teach intelligence officers to estimate the enemy’s capabilities rather than his intentions.) Many mathematicians have felt that this approach is unrealistically cautious. Recently game theorists have worked out strategies that will take advantage of a careless or inexperienced opponent without risking anything if he happens to play shrewdly. (For a relatively simple example, see diagram, fig. 3.)

The most difficult games to analyze mathematically are those in which the players are not strictly competing with one another. An example is a labor-management negotiation; both sides lose unless they reach an agreement. Another complicating factor is collusion among players—e.g., an agreement between two buyers not to bid against each other. Still another is payment of money outside the framework of the “game,” as when a large company holds a distributor in line by subsidizing him.

WHO GETS HOW MUCH?

The biggest problem in analyzing such complex situations has been to find a mathematical procedure for distributing profits in such a way that “rational” players will be satisfied. One formula has been

developed by Lloyd Shapley of the Rand Corp. An outside arbitrator must decide the payments. The formula tells him how to give the players payments appropriate to the strength of their bargaining powers, and it also maximizes the total payment. There are obvious practical difficulties in applying Shapley's "arbitration value." In the first place, the payment, or value, each player receives can seldom be measured simply in dollars. Thus the arbitrator would have a hard time deciding on the proper distribution if the players were to

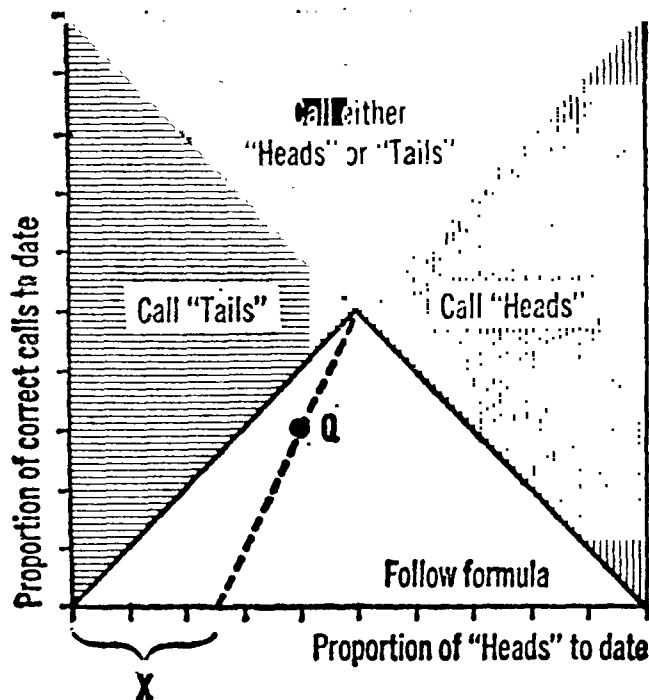


FIGURE 3.—How to play smarter than safe. Early workers in game theory designed strategies that were safe to use against infallible opponents, but mathematicians now know ways to take advantage of a careless opponent without risking anything. The diagram dictates the best strategy for guessing whether your opponent has placed a concealed coin heads up or tails up. If he were wise, he would mix heads and tails randomly, simply by flipping the coin each time. In that case, you could do no better than break even in the long run. But if he tries to anticipate your guesses, the strategy in the diagram enables you to win whenever he follows any regular pattern; and in any event you will do no worse than break even in the long run.

As the game progresses, you keep track of the proportion of times your opponent has placed the coin heads up and the proportion of times you have won. This determines the point Q . When Q is in the black or gray triangles, you follow the pure strategies shown in the diagram. But when Q is in the white triangle, you must adopt a mixed strategy, which you calculate as follows: Draw a line connecting the center of the diagram with Q and extending to the base line. The length x determines your strategy. Since x is in this case $\frac{1}{4}$, you should adopt some random way of calling heads or tails that makes it three times as likely that you will call tails. (You might put four slips of paper in a hat—three of them marked tails—and draw one.) This method takes advantage of your opponent's apparent tendency to place the coin tails up, yet it keeps him from guessing your strategy. If you follow this plan, the point Q should ultimately end up in the black triangle, which represents a profit for you.

lie about what they wanted to get from the game and how much they valued it.

While game theory has already contributed a great deal to decision theory in modern statistics, practical applications to complex human situations have not been strikingly successful. The chief troubles seem to be that there are no objective mathematical ways to formulate "rational" behavior or to measure the value of a given outcome to a particular player. At the very least, however, game theory has got mathematicians interested in analyzing human affairs and has stimulated more economists and social scientists to study higher mathematics. Game theory may be a forerunner of still more penetrating mathematical approaches that will someday help man to interpret more accurately what he observes about human behavior.

UNIVERSAL TOOL

The backbone of mathematics, pure as well as applied, is a conglomeration of techniques known as "analysis." Analysis used to be virtually synonymous with the applications of differential and integral calculus. Modern analysts, however, use theorems and techniques from almost every other branch of mathematics, including topology, the theory of numbers, and abstract algebra.

In the last 20 or 30 years mathematical analysts have made rapid progress with differential equations, which serve as mathematical models for almost every physical phenomenon involving any sort of change. Today mathematicians know relatively simple routines for solving many types of differential equations on computers. But there are still no straightforward methods for solving most nonlinear differential equations—the kind that usually crop up when large or abrupt changes occur. Typical are the equations that describe the aerodynamic shock waves produced when an airplane accelerates through the speed of sound.

Russian mathematicians have concentrated enormous effort on the theory of nonlinear differential equations. One consequence is that the Russians are now ahead of the rest of the world in the study of automatic control, and this may account for much of their success with missiles.

It is in the field of analysis that electronic computers have made perhaps their most important contributions to applied mathematics. It still takes a skillful mathematician to set up a differential equation and interpret the solution. But in the final stages he can usually reduce the work to a numerical procedure—long and tedious, perhaps, but straightforward enough for a computer to carry out in a few minutes or at most a few hours. The very fact that computers are available makes it feasible to analyze mathematically a great many

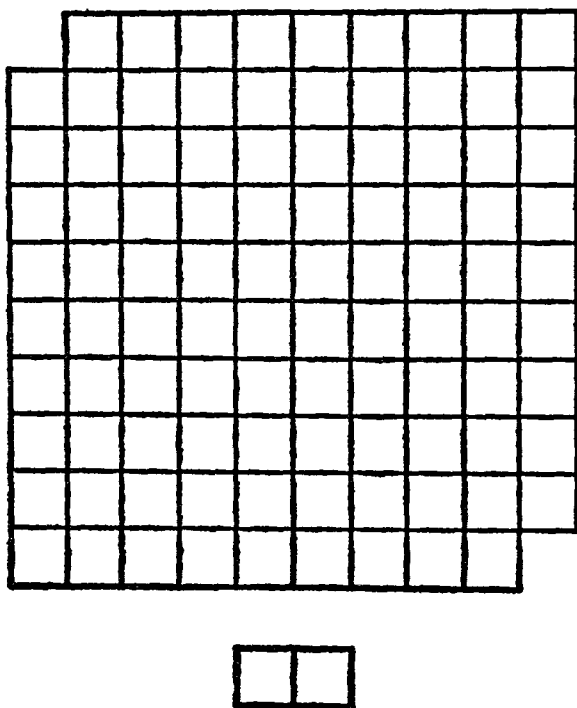


FIGURE 4.—How to make the difficult simple. Problem: Given as many of the small rectangles as you want, can you arrange them to cover completely the large figure? None of the small rectangles must overlap or jut beyond the margins of the large figure. As it happens, the feat is impossible, but the difficult thing is to prove conclusively that it is impossible. (For a mathematical solution, see fig. 5.)

problems that used to be handled by various rules of thumb, and less accurately.

MATHEMATICS OF LOGIC

Computers have also had some effects on pure mathematics. Faced with the problems of instructing computers what to do and how to do it, mathematicians have reopened an old and partly dormant field: Boolean algebra. This branch of mathematics reduces the rules of formal logic to algebraic form. Two of its axioms are startlingly different from the axioms of ordinary high-school algebra. In Boolean algebra $a + a = a$, and $a \times a = a$. The reason becomes clear when a is interpreted as a statement, the plus sign as "or," and the multiplication sign as "and." Thus, for example, the addition axiom can be illustrated by: "(this dress is red) or (this dress is red) means (this dress is red)."

Numerical analysis, a main part of the study of approximations, is another field that mathematicians have revived to program problems for computers. There is still a great deal of pure and fundamental mathematical research to be done on numerical errors that may arise

through rounding off numbers. Computers are particularly liable to commit such errors, for there is a limit to the size of the numbers they can manipulate. If a machine gets a very long number, it has to drop the digits at the end and work with an approximation. While the approximation may be extremely close, the error may grow to be enormous if the number is multiplied by a large factor at a later stage of the problem. It is generally safe to assume that rounding off tends to even out in long arithmetic examples. In adding a long column of figures, for instance, you probably won't go far wrong if you consider 44.23 simply as 44, and 517.61 as 518. But it is sheer superstition to suppose that rounding off cannot possibly build up a serious accumulation of errors. (It obviously would if all the numbers happened to end in .499.)

There are subtler pitfalls in certain more elaborate kinds of computation. In some typical computer problems involving matrices that are used to solve simultaneous equations, John Todd of the Cali-

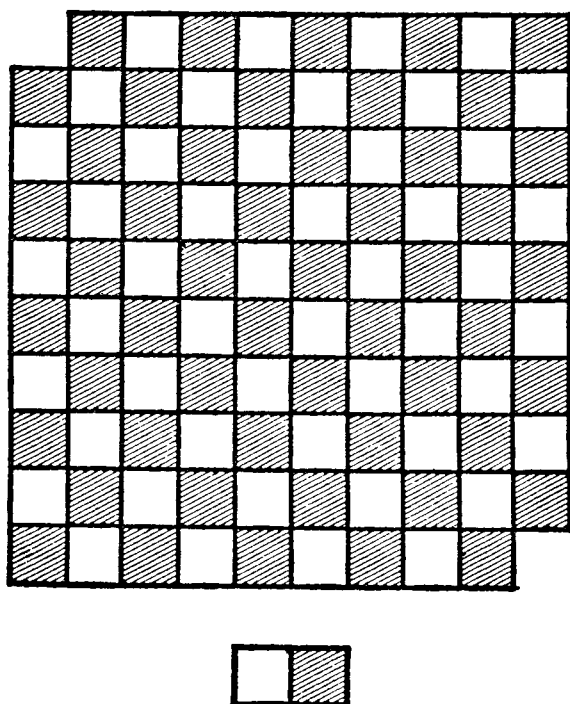


FIGURE 5.—Solution to problem in figure 4. The key to the solution is to imagine that adjacent squares have different colors, as on a chessboard. Then it becomes obvious that each rectangle has to cover precisely one black square and one white square. Since the large figure contains unequal numbers of black and white squares, there can be no way to cover it with rectangles. The solution represents a conclusive negative proof, a logical feat that is peculiar to mathematics; in other sciences negative conclusions are invariably risky. The postulation of color is a relatively easy abstraction, but it is characteristic of some of the more complex abstractions that mathematicians use to simplify problems and theorems.

fornia Institute of Technology has constructed seemingly simple numerical problems that a computer simply cannot cope with. In some cases the computer gets grossly inaccurate results; in others it cannot produce any answer at all. It is a challenge to numerical analysts to find ways to foresee this sort of trouble and then avoid it.

PATTERNS IN PRIMES

Computers have as yet made few direct contributions to pure mathematics except in the field of number theory. Here the results have been inconclusive but interesting. D. H. Lehmer of the University of California has had a computer draw up a list of all the prime numbers less than 46,000,000. (A prime is a number that is exactly divisible only by itself or one—e.g. 2, 3, 17, 61, 1,021.) A study of the list confirms that prime numbers, at least up to 46,000,000 are distributed among other whole numbers according to a “law” worked out theoretically about a century ago. The law states that the number of primes less than any given large number, X , is approximately equal to X divided by the natural logarithm of X . (Actually, the approximation is consistently a little on the low side.) Lehmer’s list also tends to confirm conjectures about the distribution of twin primes—i.e., pairs of consecutive odd numbers both of which are primes, like 29 and 31, or 101 and 103. The number of twin primes less than X is roughly equal to X divided by the *square* of the natural logarithm of X .

Lehmer and H. S. Vandiver of the University of Texas have also used a computer to test a famous theorem that mathematicians the world over are still trying either to prove or disprove. Three hundred years ago the French mathematician Fermat stated that it is impossible to satisfy the following equation by substituting whole numbers (except zero) for all the letters if n is greater than 2:

$$a^n + b^n = c^n$$

Lehmer and Vandiver have sought to find a single exception. If they could, the theorem would be disproved. Fortunately they have not had to test every conceivable combination of numbers; it is sufficient to try substituting all prime numbers for n . And there are further shortcuts. The number n , for example, must not divide any of a certain set of so-called “Bernoulli number”; otherwise it cannot satisfy the equation. (The Bernoulli numbers are irregular. The 1st is 1/6; the 3d, 1/30; the 11th, 691/2,730; the 13th, 7/6; the 17th, 43,867/798; the 19th, 1,222,277/2,310. Numbers later in the series are enormous.)

Lehmer and Vandiver have tested the Fermat theorem for all prime n ’s up to 4,000, but they seem to be coming to a dead end. The Bernoulli numbers at this stage are nearly 10,000 digits long, and even

a fast computer takes a full hour to test each n . The fact that a machine has failed to find an exception does not, of course, prove the Fermat theorem, although it does perhaps add a measure of assurance that the theorem is true.

But it is possible for a computer to produce a mathematical proof. Allen Newell of Rand Corp. and Herbert A. Simon of Carnegie Tech have worked out a program of instructions that tells a high-speed computer how to work out proofs of some elementary theorems in mathematical logic contained in "Principia Mathematica," a three-volume treatise by Alfred North Whitehead and Bertrand Russell.

The Newell and Simon program is based on heuristic thinking—the kind of hunch-and-analogy approach that a creative human mind uses to simplify complicated problems. The computer is supplied with some basic axioms, and it stores away all theorems it has previously proved. When it is told to prove an unfamiliar theorem, it first tries to draw analogies and comparisons with the theorems it already knows. In many cases the computer produces a logical proof within a few minutes; in others it fails to produce any proof at all. It would conceivably be possible to program a computer to solve theorems with an algorithmic approach, a sure-fire, methodical procedure for exhausting all possibilities. But such a program might take years for the fastest computer to carry out.

Although most mathematicians scoff at the idea, Newell and Simon are confident that heuristic programming will soon enable computers to do truly creative mathematical work. They guess that within 10 years a computer will discover and prove an important mathematical theorem that never occurred to any human mathematician.

HELP WANTED

But computers are not going to put mathematicians out of work. Quite to the contrary, computers have opened up so many new applications for mathematics that industrial job opportunities for mathematicians have more than doubled in the last five years. About one-fourth of the 250 people who are getting Ph. D.'s in mathematics this year are going into industry—chiefly the aircraft, electronics, communications, and petroleum companies. In 1946 only about one in nine Ph. D.'s took jobs in industry.

While most companies prefer mathematicians who have also had considerable background in physics or engineering, many companies are also eager to hire men who have concentrated on pure mathematics. Starting pay for a good young mathematician with a fresh Ph. D. now averages close to \$10,000 a year in the aircraft industry, about double that of 1950 (and about double today's starting pay in universities).

Still, a great deal of industrial mathematics is done by physicists and engineers who have switched to mathematics after graduation. And there is also room for people with bachelor's and master's degrees, particularly in programing computers to perform calculations.

Different companies use mathematicians in different ways. Some incorporate them in research teams along with engineers, physicists, metallurgists, and other scientists. But a growing number have set up special mathematics groups, which carry out their own research projects and also do a strictly limited amount of problem solving for other scientific departments.

The oldest and most illustrious industrial mathematics department was set up in 1930 by Bell Telephone Laboratories. It started with six or eight professional mathematicians and grew slowly until after the war. Then in 10 years it doubled in size. Today the department has about 30 professional mathematicians, half of them with Ph. D.'s in mathematics, the rest with Ph. D.'s in other sciences. The department has made outstanding contributions to mathematics. Notable is information theory, which was developed during and after the war by Claude Shannon as a mathematical model for language and its communication.

CRISIS IN EDUCATION

The demand for mathematicians of every sort is rapidly outstripping the capacity of the U.S. educational system. Swelling enrollments in mathematics courses are already beginning to tax college and university mathematics departments. At Princeton, for example, the mathematics majors have for years numbered only 5 to 10, but 19 members of last year's junior class elected to major in mathematics. To complicate matters further, the good college and university departments no longer require their professors to teach 12 to 15 hours a week. So that the teachers can also do research, the average classroom time has been reduced to 9 hours in most schools, and to less than 6 in some of the best universities. Yet the serious mathematics student now needs more training than ever before. If he wants a good job in industry or in a top university, he must have a doctor's degree; and if he wants to excel in research, he should have a year or two of postdoctoral study.

There is a great deal to be mastered in modern mathematics, but surprisingly it is relatively easier to learn than most of the mathematics traditionally taught in high school and college, despite its abstractness and complexity. One change that would obviously help would be to start teaching the important modern concepts and techniques earlier. The way mathematics is taught now, complains John G. Kemeny of Dartmouth, "it is the only subject you can study for 14

years [i.e., through sophomore calculus] without learning anything that's been done since the year 1800."

THE DARTMOUTH PLAN

Some colleges are now making progress in modernizing their mathematics curricula. Several no longer require a special course in trigonometry. "We really don't have to train everybody to be a surveyor," explains one department head. Under the leadership of Kemeny, Dartmouth in the last 5 years has almost completely revised its undergraduate course. There are now, in fact, three separate courses of study in mathematics: one for mathematics majors, another for engineers and others who must have mathematical training, and a third for the liberal-arts students who want to make mathematics part of their cultural background.

The courses are amazingly popular. Ninety percent of all Dartmouth students take at least one semester of mathematics, and more than 60 percent finish a year of it (mathematics is an elective for most of them). Kemeny and two associates have written for one of their courses a remarkable textbook entitled "Introduction to Finite Mathematics." Within a year after its publication in January 1957, it was being used by about 100 colleges, in some cases just for mathematics courses especially designed for social-science majors. And several New York high schools have adopted the book for special sections of exceptional students.

MATHEMATICS FOR CHILDREN

The movement to teach more mathematics and teach it sooner has filtered down to the secondary-school level. The College Entrance Examination Board, through its commission on mathematics, has drawn up a program for modernizing secondary-school mathematics courses. The chief aim of the commission, according to its executive director, Albert E. Meder, is to give students an appreciation of the true meaning of mathematics and some idea of modern developments. Algebra, he points out, is no longer a "disconnected mass of memorized tricks but a study of mathematical structure; geometry no longer a body of theorems arranged in a precise order that can be memorized without understanding."

The College Board has the support of most leading mathematicians. About 20 of them are meeting with 20 high-school mathematics teachers this summer at Yale to write outlines of sample textbooks based partly on the College Board's recommendations. This group, headed by E. G. Begle of Yale, plans to write the actual books within the next year so that teachers and commercial publishers will know how mathematicians think mathematics ought to be taught in high school.

Perhaps the most radical step in U.S. mathematical education has been taken by the University of Illinois' experimental high school. There, under the guidance of a member of the university's mathematics department, a professor of education, Max Beberman, has introduced a completely new mathematics curriculum. It starts with an informal axiomatic approach to arithmetic and algebra and proceeds through aspects of probability theory, set theory, number theory, complex numbers, mathematical induction, and analytic geometry. The approach reflects the rigor, abstractness, and generality of modern mathematics. To make room for some of the new concepts, Beberman and his advisers have had to reduce the amount of time spent drilling on such techniques as factoring algebraic expressions.

So far the experiment has been very stimulating to students—partly, of course, because of the very fact that the course is an experiment. In the college entrance examinations of 1957, the first group of students to complete 4 years of the Illinois course made some of the highest scores in the nation.

While 12 other high schools have now experimentally adopted the Illinois mathematics curriculum, it is not likely to be widely used for some time. The reason is that most high-school teachers have to be completely retrained to teach it. With Carnegie Foundation support, the University of Illinois has begun to train high-school teachers from many States to teach the new curriculum.

For many years it has been hard for a would-be teacher to learn what mathematics he needs to teach any serious high-school course. Prof. George Polya of Stanford explains: "The mathematics department [of a university] offers them tough steak they cannot chew, and the school of education vapid soup with no meat in it." The National Science Foundation has helped more than 50 colleges and universities set up institutes where high-school teachers can study mathematics for a summer or even a full academic year.

OPPORTUNITY AHEAD

However many mathematicians there may be, there will always be a need for more first-rate minds to create new mathematics. This will be true of applied mathematics as well as pure mathematics. For applied mathematics now presents enough of an intellectual challenge to attract even academic men who pride themselves on creating mathematics for its own sake. One young assistant professor, recently offered \$16,000 by industry, is seriously thinking of abandoning his university career. He explains: "I think that the problems in applied mathematics would offer me just as much stimulation as more basic research."

Whole new fields of mathematics are needed to cope with problems in other sciences and human affairs. Transportation engineers, for example, still lack a mathematical method to analyze the turbulence of 4-lane highway traffic; and it may be years before they can apply precise mathematical reasoning to 3-dimensional air traffic. Biologists have used almost no mathematics aside from statistics, but now some of them are seriously thinking of applying topology. This branch of mathematics, which deals with generalized shapes and disregards size, may be the most appropriate way to describe living cells with their enormous variations in size and shape. Neurophysiologists are looking for a new kind of algebra to represent thinking processes, which are by no means random, yet not entirely methodical.

There are still some remarkably simple questions that are teasing mathematicians. They have not yet found, for example, a general solution to the following problem: Given a road map of N folds, how many ways can you refold it? And when this is solved, there will be another puzzle, and another.

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Mirages

By JAMES H. GORDON ¹

[With 1 plate]

MEN have been seeing mirages and wondering about them for thousands of years. They must have talked about them, too, but when it came to writing about them, the subject seems almost to have been taboo. Nothing about them appears in the literature of the Egyptians or other early civilizations, or in the writings of the Greeks or Romans. They are not mentioned in the Bible, by Marco Polo, or by writers about the Crusades. Perhaps not too long after the Crusades, a recurring mirage seen over the Straits of Messina was given a name—*Fata Morgana*. In 1798 a physician with Napoleon's army in Egypt wrote about appearances of water on the desert. To the best of my knowledge, only one mirage is mentioned in American history; that was in 1878, when Custer's little army marched away from Fort Abraham Lincoln to play its tragic part in the Battle of the Little Big Horn. Farewells said, the force had passed out of sight when to those left in the fort a mirage showed the column marching away through the sky, each man and horse clear.

Another mirage story is told of World War I days when Allenby's army was moving north from Egypt against the Turks. The two forces had met and were joined in a great battle, with the stronger Turkish army slowly gaining the advantage. A Turkish outpost rushed word in to the high command that strong British reinforcements had been seen moving up, possibly to attack the flank. A hurried conference decided that the Turkish army should break off the battle and withdraw, which was done. But there had been no reinforcements. What had been seen was a mirage—one that had a hand in the making of history. I have not been able to verify this story.

Mirages of course act strictly in accordance with the laws of nature, though it may seem that these laws are used with a bit of poetic license at times. Two of them are so deeply involved that they might well be called the mirage makers. One has to do with the density of

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air as affected by temperature and pressure; the other governs changes in the speed of light, and, incidentally, its direction, as it passes from an air layer of one density into that of another. There are two other factors involved—junior partners that have a definite hand in the business, to be discussed later. Watching a mirage, one often gets the impression that it is a directed performance, and one well done.

The widespread belief that a mirage is something unreal, a sort of trick played on the eyes, is wrong. The picture a mirage presents is real but never quite accurate. The effect of the mirage is to change the seeming location or appearance of an object—not infrequently, both. The seeming shift in position may be hardly noticeable or may amount to many miles; change in appearance may be slight or extensive. Both of these changes are brought about by refraction; that is, a bending in the course of the light path from object to observer. The bending occurs when light passes from dense to less dense air, or vice versa. Most of us remember the example of refraction we were shown in school when a spoon was placed in a glass full of water. Looked at from an angle, the handle seemed to bend sharply where it entered the water. Whereas the difference in the densities of air and water is comparatively great, that between two layers of air is very slight, so that the bending would be almost infinitesimal. A succession of such bends, however, could bring about an appreciable change in direction of the light path. To do this—and it is necessary for mirage making—a mass of air must have a progressive and abnormally great density change within it. The function of such an air mass as a bending or refracting agency, similar to that of the lenses in our optical instruments, seems to justify calling it an air lens, at least until a better name offers. Physically it bears little resemblance to our optical lenses. Its depth may vary from an inch or two to a hundred feet or more and its area from a few square feet to many square miles. Because it is composed of air and is surrounded by air, except where it rests on the ground, its boundaries are often hard to ascertain. The evidence at hand indicates that the lens is likely to be approximately flat and to operate chiefly in a horizontal position, since bending of the light path is mostly up and down, not sideways.

It is not easy to accept the fact that a certain mass of air, surrounded by other air, can be maintained as a separate entity and do things the surrounding air cannot do; that it can continue as a thing apart for some time, strongly resisting integration. A demonstration of this type of phenomenon came to my notice in the Norris Basin of the Yellowstone Park a number of years ago. Norris Basin is an area of many small geysers which intermittently spew up steam and water a few feet into the air. Runoff from the many small geyser basins is

carried away by a shallow stream perhaps 8 feet wide. Some little distance below the last inflow there is, or was, a small footbridge spanning the brook and offering an excellent view of its gravelly bed. This was made up of parallel strips of color—reds, browns, greens, yellows, blues, and so on—not much more than an inch wide with lines between them sharply drawn. Each stripe represented the streambed carrying the flow from some particular geyser. Algae, differing in color, had adapted themselves to the temperature and mineral content of the various basins, and the overflow carried some of them with it to find a new home on the pebbles and gravel of the streambed, each one marking clearly the flow from its own basin. These little streamlets had flowed along for some distance without mixing, and so continued as far as the eye could follow. They presented visible evidence, thanks to the algae, of the ability of a stream of water, probably with slight difference in density from its neighbors, to keep its separate identity while flowing along in contact with other streams. If it had not been for the algae, this phenomenon would have been as invisible to us as most of the air lenses in the general airmass.

Getting back to these lenses, let us look at the diagrams (fig. 1) which attempt to make clear how or why a bending in the light path occurs; then, by making use of the air lens in the two positions, dense side up and less dense side up, how the effects are brought about. Results from the two positions of the lens differ so radically that it seems best to designate them as lenses No. 1 and No. 2. The function of No. 1, denser at the top than at the bottom, is almost exclusively that of making water seem to be where there is none. As the diagram shows, lens No. 1 will make an object seem to be lower than it actually is. The object is usually a bit of blue sky near the horizon which is made to appear on a road or on a dry lake bed, where it looks like water. This lens will be formed almost exclusively in contact with sun-heated ground or roadway, but it has also been observed against walls heated by the sun. It has been formed in the laboratory as well.

The No. 2 lens, denser at the bottom than at the top, has the reverse effect of No. 1 in that it makes an object, or part of it, seem to be higher than it is. The activities of No. 2 lens produce three types of effects: (1) The lens when lying on a ridge between object and observer, almost invariably produces a good, clear picture of some object, normally hidden behind the ridge, that is lifted into sight by the mirage. (2) When the lens is in the temperature inversion layer of the atmosphere from a few feet to thousands of feet above the ground, it can distort the appearance of an object, in addition to raising it up. (3) Also, when the lens is in the temperature inversion layer, it can pick up and transport a picture or image and show it a few miles or hundreds of miles away. The picture may be erect or inverted, and sometimes

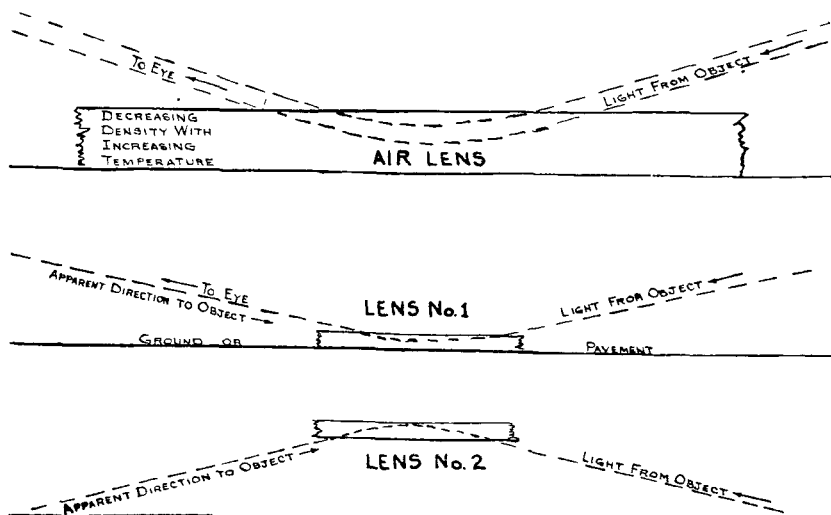


FIGURE 1.—Mirage formation depends on a lens of air similar in function to lenses in our cameras and telescopes. Density of the air forming it must increase or decrease progressively from top to bottom. Speed of light increases as it moves into less dense air, and conversely. In the first diagram, the left side of a shaft of light enters the lens first, picking up speed. At all times, while within the lens, it is in thinner air and moving faster than the right side, covering the longer arc while the right side covers the shorter one. The result is a change in direction of the light path. As drawn the center diagram would be known as lens No. 1 with the quality of making the object of the mirage seem lower than it is. Turned over, as in No. 2, it works equally well in making the object seem higher than it is in reality. No. 1 nearly always rests on the ground. No. 2 may be on a ridge, between object and observer, or aloft in the free air. To facilitate drawing, change in direction as shown by diagrams is made much greater than we find in nature, as is the depth of the lens in proportion to diameter. Because the rate of density change is rarely uniform, the path of direction-change arc is unlikely to be a simple curve. Its penetration is likely to be at, or near, the bottom of lens.

both positions are shown. Actually, of course, mirage making is often not nearly so simple as might be inferred from the diagrams.

Some types of mirage, such as the seeming strip of water in the road, or water in a dry lake bed, may be seen very frequently. Others appear often during certain seasons of the year. Wind, humidity, cloudiness, or storm can effectively interfere with their habits. Then there are those that appear only several times a year or once in a number of years, or even once in a lifetime or within the memory of man. (One of my best mirage stories is nearly a hundred years old and is apparently the only such appearance over that little town in all that time.) They are seemingly phenomena of habit, showing in the same place over and over again and, just as stubbornly, not showing in other places. Mirages do not broadcast their pictures as does a moving-picture screen; they may be seen only from a limited area, established by the lens's angle of refraction. In the case of the No. 1 lens, the field of observation is sometimes a broad-rimmed circle completely surrounding the mirage. Actually as we move around that circle, the bit of sky pictured is constantly changing, but it looks the same.

The commonest mirage in our desert country today is a seeming strip of water on the highway which appears when we are at some distance and vanishes as we come near. The frequency of this type is a modern development, paralleling that of the automobile and paved highways; it was very rarely seen on the old dirt roads. Frequently it may show the seeming reflection of an approaching car or, after sundown, its headlights in the seeming water. An asphalt surface is its favorite location. On warm afternoons, the air temperature next to this surface may be 10° higher than that an inch above, 20° higher than 6 inches above, supplying the foundation for an air lens.

Perhaps you have wondered why these little mirages appear only on scattered parts of the road surface. Their location is definite; they do not move with you. If you had looked back you probably would have seen the first one pop into sight again after you had gone a hundred yards or so. But there would be long stretches with none at all, in spite of the sun's beating down on the surface. These mirageless areas have long been a puzzle. Looking for an explanation, I took a series of temperature readings about 3:30 on warm June afternoons in a mirage-forming area and in a nonforming one about 10 feet away. The bulb was held at the surface, barely above it, up one-third inch, 1, 2, 3, 6, and 12 inches. There was appreciable wind movement at all times. To make sure the temperature shown by the bulb was not affected by direct radiation from the asphalt, a sheet of paper was interposed between the two, resulting in negligible change. Readings in the two locations were practically identical. The mirage-forming area seemed to be surrounded by other air with just as favorable conditions. The only hint of an explanation seemed to be found in the fact that there was certainly a general tendency for mirage-forming areas to be in depressions. They might be quite appreciable or so slight as to be hardly more than a token, such as the converging cracks in the surface or depressed lines left by street repair.

It was said for years that the reason mirages were so much more common over asphalt than over dirt was that the black surface became so much hotter under the sunshine. To test this, comparative readings were taken in the same manner as described earlier, over two small mirage-forming areas of the asphalt about a hundred feet apart, and in several locations over the dry, loose soil of an adjacent vacant lot. Results were so unexpected that 12 sets of readings were taken. Surface-temperature readings over the dirt ran from 6° to 10° higher than over the asphalt, this difference gradually growing smaller with elevation. Actually, the difference was logical enough, and any bare-foot boy could have told you that the dirt was hotter. Asphalt is a much better conductor of heat than dry dirt. Heat absorbed by the pavement was carried down and distributed throughout the mass,

whereas that absorbed by dry soil piled up at or near the surface. Any extra absorption by the black surface was more than offset by poor conductivity of the soil, and this, naturally enough, was reflected in the temperature of the overlying air. Readings taken at midnight and sunrise bear out this explanation. At those times, temperatures immediately over the pavement, still pouring out its stored-up heat, were from 5° to 8° higher than over the ground, which had radiated its near-surface heat rapidly. Just after sundown, the two were about equal.

There is still left the question as to why the superheated air over the ground and so much of the pavement was not mirage forming. The ground had many depressions which seemed to have no value at all for that purpose. Pursuing the question a little further and not having cement paving available for testing, I took temperatures over the cement sidewalk. They ran fairly close to those over the asphalt. The relatively small number of these mirages over cement paving, even when blackened by oily exhaust, may be explained by the method of laying. The asphalt is rolled on, making quite possible the formation of across-street depressions. The cement is poured on and leveled while wet, eliminating most such inequalities.

In warmer weather, the seeming water in the little strips frequently spreads until it covers the whole street, gutter to gutter, for several blocks. At about a hundred yards only the normal strips will be seen; then at approximately double that distance, the spread area will begin. This will occur only where there are already strips—never, in my experience, in other areas of the pavement. It is evident that the angle of refraction for the responsible air lenses is only half as great for the spread area as it is for the strips.

In the spring of 1959 use of 7×50 binoculars in the study brought added information on the makeup and behavior of these street mirages. Kneeling or sitting, to meet the light path lower down, one may cut the observing distance from them in half. The mirage itself, of course, gives us the shape and size of the air lens. In effect, the transmitted light colors the air forming the lens much as a stain brings out the details of a microscope slide. One might almost get the effect of looking at the mirage through a microscope.

Particular attention is called to a study made early in June of one of the spread areas. The nearer strips of seeming water were in evidence, but the larger mirage covering the street from gutter to gutter and extending, with some breaks, for about three blocks was most interesting. A brisk south wind, 12 to 15 m.p.h., was blowing across the street. Street surface was asphalt about 35 feet wide with cement gutters 18 inches wide. The spread-area mirage and the air lens that caused it had irregular across-the-street boundaries but sharp lateral ones. On both sides, as it reached the line between

the asphalt street surface and the cement gutter, it stopped short. The air forming the lens was colored by the transmitted light so as to be clearly visible. The lens seemed to be formed of a scurrying, shimmering blue blanket of heat waves about 2 inches thick. In the brisk wind the air forming the lens must have been changed every 3 or 4 seconds. Moving across the south cement-asphalt dividing line, it became instantly visible, a part of the functioning, mirage-forming lens, passed out of it, and vanished at the north line. Cars and trucks passing through it in a steady stream had no visible effect; there seemed to be no piling up against the windward side of tires. The lens arched up over the crown of the road, fully a foot higher than the gutter.

What mysterious force within that lens maintained it as a functioning entity amid all those disruptive forces? It was composed of air that was changed every few seconds, surrounded by air except where it rested on the ground, and yet it was completely set apart, doing things the surrounding air could not do until it moved into the lens, and could no longer do the second it moved out. The assumption of the mirage-making power the instant the air crossed the south cement-asphalt line was something to see and wonder at.

Earlier in this paper reference was made to the two laws most deeply involved in mirage making and their two rather mysterious junior partners. One of these two junior partners would seem to be concerned with the forces that set the lens apart and keep it that way; the other with the need to select the location in which a lens will operate. How they carry out these functions we do not yet know. Because of the wind, the effects shown in this mirage were almost miraculous, but its lessons were borne out in other locations.

There is an almost comic side to these hard-fighting, long-lasting street mirages—they cannot stand competition from real water. A brisk shower or even a sprinkling cart can bring an end to them in seconds.

At this point it is well to consider the extreme contrast between what we have been watching and the lenses that operate for only a fleeting moment to give us the filmiest of pictures, sometimes recurring, sometimes not. In my experience these momentary showings are not common. My most impressive example was the appearance of a great towering block of mesa, seeming quite near, reaching much above my little watchtower hill, completely unreal, without substance, and yet easily seen. It probably lasted more than a minute. It was impossible to say what real object might have been so distorted.

Related to the little mirages in particular, but having also to do with mirages in general, is the following fairly typical case. At a distance of 200 yards or more the seeming water will appear and will

remain in sight for about a hundred yards of approach, then vanish. At 200 yards, with eyes 6 feet from the ground, the total change in direction of the light path would be about 1° , at 100 yards around 2° , giving a tolerance of about 1° through which refraction operates. Two degrees is probably the maximum bending found in nature as produced by an air lens. It seems probable that the minimum bending effective in mirage making is well under one-quarter of a degree. The bending potential of one of these small in-the-road lenses depends on its great density change within a shallow depth. It must have that to contain its direction-change arc within its small diameter. The same bending capacity might be found in a much larger lens where the same density change is spread over many feet, instead of a few inches, and where the direction-change arc has a possible length of miles.

For classic mirage effects, no other location can equal an old dry lake or sea bed. Bets have been won and lost over the reality or unreality of what seems to be a beautiful body of water often reflecting the nearby trees and hills. Sometimes, even in dry country, it is real water that complicates the betting. From a little distance it is indeed difficult to tell real water from a mirage. The seeming lakes vary greatly in size, from perhaps an acre to many square miles. The small mirages have a decided prejudice against operating over ground surfaces. The larger mirages are particular—just any ground will not do—but an old, level-floored lake bed or sea bed fills the bill beautifully. It has been my experience that the angle of refraction of these larger mirages is much flatter than that of the small ones, so that they must be viewed from a greater distance. Willcox Dry Lake bed mirages in southeastern Arizona are an illustration of this. With some 50 square miles of almost completely flat surface, the bed offers very frequent showings. Easily seen from the highway, it is as worthy of a stop as many of the beautiful real lakes. It is an experience to remember to see the great dry lake bed of early morning give away to the seeming beautiful blue water with changing lights and shadows through the day, and a fading out toward evening. Many of the mirage lakes not only show reflections of nearby trees and hills, but have islands, capes, and bold headlands, even very real-looking ships sometimes, and, rarely, a shimmering white city on the far shore. These mirage effects can stand quite a bit of wind. Rippling effects are not uncommon, and I have had reports of waves seeming to be breaking on the shore. A railroad trainman told me of having his train seemingly isolated on an island, wheels of the rear cars deep in the mirage water. There have been reports of planes coming down to land on some of these lakes, specifically one south of Las Vegas, Nev., and of flocks of ducks sweeping over for the same

purpose. Stockmen tell me that a mirage may fool men and ducks but never stock. It just does not smell like water, and cattle refuse to be interested, even if very thirsty.

A rather infrequent activity of the No. 1 lens is far removed from making water seem to be where there is none. In its role of making an object seem to be lower than it is, it sometimes makes a mountain range low on the horizon seem to drop out of sight. Since the range is, with the effect of distance, already very little above lens level, light from it would have difficulty entering the top of the lens unless it should be on a slope dropping away from the observer. In that case, the light path could be turned up to pass over the head of the observer, or if there were no slope, light could enter the far side of the lens and be turned up with the same result.

Is it possible that this might be in conflict with the celestial mirage effect which makes sun and moon and stars seem to be higher above the horizon than they are, if the sun, for instance, were setting behind that particular range?

Mention has been made of the three widely different activities of the No. 2 lens. Names in the modern manner have been chosen to identify these activities: Operation Liftup, Operation Distortion, and Operation Long Distance.

Normally, temperature and density of the air decrease steadily with elevation. Under such conditions neither No. 1 nor No. 2 lenses could be formed. As we have seen, a superheated ground surface raising the temperature of the air immediately above it reverses the density trend and we get a No. 1 lens. Over a cold ground surface, and frequently aloft in the atmosphere, the temperature trend is reversed, stepping up the rate of density decrease. Sometimes, and in certain locations, this abnormally steep density gradient will result in the formation of a mirage-forming air lens.

OPERATION LIFTUP

For Operation Liftup, such a lens may be formed over the cold ground surface of a ridge about midway between, and higher than, the object and the observer. Based on the ground, it will be, in effect, saddled over the ridge, and light can not reach it from below, as shown in the diagram. Apparently instead, light enters the object side of the lens, follows its curve over the ridge, and escapes the opposite side to pass down the slope to the observer. This lens can pick up the image of a house or a town or a mountain range hidden behind the ridge and lift it into sight. Within my experience and judged from evidence from the many stories I have heard, it invariably turns out a clear, sharp picture, without distortion. A friend told me of seeing, as a boy, a neighbor's house over the ridge lifted into sight so clearly that he could recognize the children playing about. In the

Imperial Valley one of the watermasters told me he had twice seen trains puffing along in the sky, lifted into sight over the massive bulk of the sandhills. From a ranch house on the edge of the mesa some 20 miles south of Yuma, the owner frequently sees the little town of San Luis across the border in Mexico, which normally is not visible, lifted into sight, together with its highway and speeding cars. A ridge east of the New Yuma Hospital normally hides homes and ranches beyond it. Two or three times a year, on the average, they are lifted into sight. In eastern Colorado rolling hill country, ranchers frequently see on still mornings homes and farms as much as 20 miles away. The picture is lifted up, into sight, but not otherwise changed.

In the mirages studied so far, we knew where the lenses were—in the street, dry lake bed, or on the ridge—and could go to them, take their temperatures, etc. In our study of other types, that advantage is lacking. Their lenses are in the temperature inversion layer aloft, a few feet to several thousand feet above the ground, well out of reach. Balloon-carried instruments giving temperature, humidity, and pressure are sent up four times a day from many places over the world, frequently passing through these layers, but their data, as bearing on temperature inversion layers, have not been tabulated. As far as known, no balloon run has been made up through a mirage-forming layer to give us a definite picture there. These layers are commonplace over all parts of the world, almost as much so as clouds, and as transient. We know that the amount of the inversion varies greatly, as does the thickness of the layer and its area. From the mirage itself we may draw certain conclusions. For the building up of a certain effect, the lens and its sustaining layer must have certain qualifications. It seems probable that much less than a tenth of 1 percent of the inversion layers ever become mirage forming, and so it is evident that this is one of their minor activities.

Aloft, as over the asphalt pavement, the lens picks its location carefully, and having picked it, uses it over and over again. It is evident that in all cases, the terrain, including the surface over which the lens is to form, is of the greatest importance. The mirage will come into being because, at the proper place between object and observer, the terrain makes possible the formation of an effective air lens, on the ground or aloft. Of course the weather must cooperate.

OPERATION DISTORTION

Operation Distortion, carried on in some particular temperature-inversion layer aloft, functions to make some object or scene look as it does not. The primary effect it achieves is a stretching up. This may be followed by a lateral stretching, mostly internal, as between the stretched-up parts of the object or scene—houses in a town, hills

or mountains in a group, etc. There may be also a lifting of the whole distorted object or scene. Oddly enough, these operations are carried out mostly over water surfaces not far from shore and over near-desert areas. Examples are the famed Fata Morgana over the Straits of Messina, similar effects off the northern Japanese Islands, off our New England coast, over the Great Lakes, off the California coast near Santa Barbara, and so on. The desert country, too, specializes in them; that is where I have seen them. They may be very near. A man crossing a field may develop stiltlike legs, freight cars on a siding may seem to stretch up to more than double height, a row of trees may stretch far up. Then there are a wide variety of forms of great complexity.

Mirages are definitely not photogenic. To the eye and through binoculars they often look substantial enough, but I have repeatedly seen the mirage image of a distant mountain through the image of a nearer one, which lack of substance perhaps the camera recognizes. Distance to the mirage is often great enough to be a photographic problem. Probably the best explanation of the almost complete absence of mirage pictures is the infuriating fact that on the rare occasions when a good picture might be had, one never has his camera and there is not time to get it.

Lacking photographs, I have drawn a number of silhouettes to show some of the mirage forms and processes occurring in the desert. Between object and observer and evidently essential for the formation of the temperature-inversion layer which must supply the huge air lens needed, there must be a large area of approximately flat land, frequently many square miles in size. This may be drawn in, in your imagination.

In the mirage known as Flattop (fig. 2), elevation of the highest hill in the group, for reasons not known, always seems to establish the height of the whole structure. The lesser ones build up to that height. The building process may stop at any point and reverse itself, sometimes for a fresh start, sometimes to end the show for the day. It is an amazingly deliberate and systematic operation, proceeding to follow the pattern exactly, time after time, year after year, in this place and others. Apparently depending on the lay of the land between object and observer, there are probably half a dozen or more variations on this general procedure, but none of those variations forms a flattop.

Such a full development as the drawings show may come about in perhaps 15 to 30 minutes. The completed picture never appears suddenly. The image must be built up according to rule and removed the same way.

Watch, if you will, how it grows. From the lower hills, perhaps no more than a knob on the horizon, a feeler reaches up to the height

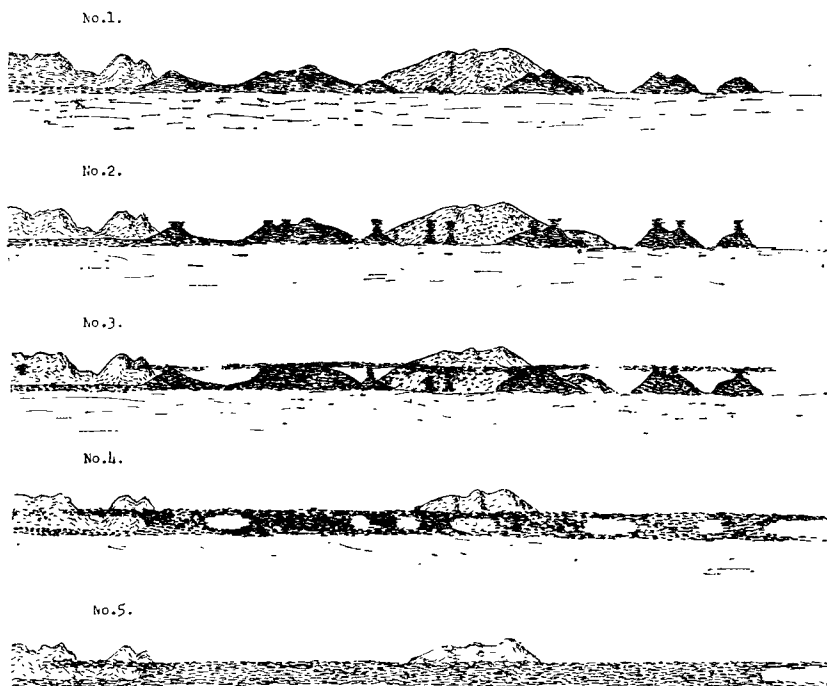


FIGURE 2.—Formation of the Flattop mirage by stages. No. 1, Normal skyline; No. 2, feelers reach up to height of highest peak, and having reached it, flatten out; No. 3, streamers extend from flattened tops until they meet, also from end hills; No. 4, windows formed filling in; No. 5, windows completely filled giving a seeming flattop mesa replacing old skyline. About 75 percent of these mirages stop development between stages 3 and 4. Unmaking exactly reverses routine of building.

of the highest peak. Touching it, as though reaching a ceiling, the top flattens out. From the flattened tops streamers reach out until they meet others from right and left. The openings or windows thus formed fill in slowly, from all sides, like the diaphragm of a camera, until the window is closed and we have a seeming flattened mesa in place of the old irregular skyline. Streamers have also reached out from the end hill masses for perhaps a mile or two. Sections of these streamers may lose contact with their base and join up again or, more rarely, persist by themselves after the parent mirage has ceased to be. In the mesa face, windows may appear and fill in again; the display is not static. Finally, usually within an hour, windows appear and grow, the streamers and flattened tops draw back, the feelers fade away, and we have our group of broken hills again.

This building and unbuilding of the mirage must be the result of progressive buildup and breakdown in the temperature-inversion layer and in the air lens it creates. At some point in this development the lens becomes capable of producing the effect of feelers

reaching up to a common level; next comes the effect of feeler tops flattening out and extending to meet others to form windows, and then to fill in the windows. The completed flattop seems to be a climax, the highest point of development the inversion layer and lens can reach. In the unbuilding, these steps are reversed. The mirage has furnished us with some idea of what has been going on in the lens and has made it visible, somewhat as the colored algae in Yellowstone Park outline the course of each little stream in the brook.

The Flattop seen some 35 miles southeast from Yuma is a late starter, rarely seen before 7:30 a.m. As a rule, about sunrise is the best time to see such mirages.

A very unusual development of this Flattop building technique was observed at Naco, in southeastern Arizona, one morning in the late winter of 1916-17. Five or six miles to the east is a barren, sawtooth line of hills, rising perhaps 250 to 300 feet. A bit before sunrise rising feelers were noted on those hills, followed by the usual routine; tops of feelers flattened out, streamers met, and windows filled in, to form a flattop. Out of this was built up again the jagged skyline which developed into a second flattop, and a third story was built on top of that. Two or three minutes later, the unbuilding began, unhurriedly, following the rules exactly, top story, second, and finally superstructure of the first, to leave only the bleak, dark profile of the hills. All this, fitted in between setting-up exercises and breakfast call, was observed by hundreds of men of the First Arizona Infantry and others of the 10th U.S. Cavalry, camped next to us, on border duty following Villa's raid on Columbus.

In this case, evidence offered by the mirage points to the fantastic conclusion that there were three nearly identical temperature-inversion layers cooperating with beautiful precision. When the lens of the first reached its climax, the lens of the second took over, and the third after that, and they worked the same way with the unbuilding. The inversion layers may have formed some little distance apart at slightly different levels and drifted together; this is by no means impossible to imagine. Use of lenses in these layers to do the building and unbuilding is however, quite beyond our imagining, as are many of the phenomena in Operation Distortion. This three-story effect is completely without precedent in my collection of mirage lore. Of the watching company, a good proportion of them ranchers, cowboys, prospectors, outdoor men, no one I talked to had seen anything of the sort before.

I understand that in certain recent atmospheric studies radiosonde equipment was sent up by a captive balloon to work at any desired level and send back much fuller information on that level than a regular run could provide. It would be most interesting to make such

a study of what goes on in some of our mirage-forming layers, provided we knew where the layer was and further provided that very light winds cooperated to let the balloon and instruments stay where wanted.

The second distortion pattern shown, the Portal Mirage (fig. 3), is a much less formal one and, in my experience, much less frequent. It may appear quite suddenly. Its invariable habit of leaving passageways between the built-up hill masses is characteristic and suggests the name. It is not flattopped and does not send out streamers. The normal hill profile seems rather to be lifted and partially flattened out. Its height, in the same group of hills as Flattop, differed very little. In a recently observed case, the area of the temperature-inversion layer, at least the effective part of it for mirage building, must have been quite small and moving. Buildup started at the west end of the line of hills and moved eastward, building as it went. Before the east end of the line had been reached, westernmost hills were back in normal shape. It causes one to wonder why, once or twice a season perhaps, the Flattop routine is interrupted for a day by this pattern.



FIGURE 3.—The Portal mirage. This is a considerably less common form than Flattop, in the writer's experience, but based on the same group of hills. Its behavior is much more informal than Flattop's, often much more hurried in the making and unmaking. Streamers do not seem to be any part of its pattern. It seems to keep some of the skyline of the hill, considerably flattened and lifted. It has the invariable habit of leaving passageways between the hill masses, hence its name.

A very different type of distortion was observed from my lookout hill in the early spring of 1951. Some 75 or 80 miles to the southeast, across the broad delta plain of the Colorado River, rises the Cocopah Range some 1,800 to 3,000 feet high with skyline only gently irregular, with no noticeable peak. On this particular morning, less than an hour after sunrise, the sky was heavily overcast with altostratus clouds, making it an unusually dark morning for this desert country. Well off to the southwest there must have been a break in the clouds, not showing, but letting a shaft of sunlight through. The mirage makers had been really busy. It looked as if they had scraped together all the material in the 50-mile-long Cocopah Range and piled it up into a great Fujiyama-like peak well over twice as high as the range itself. The shaft of sunlight spotlighted this mountain and it shone splendidly, like a vision, the only bright spot in a dark and gloomy world. I watched it for 10 or 15 minutes through binoculars. The range to right and left was completely blotted out, as if a dirty whitewash brush had been drawn through that part of the picture. In spite of the distance, such brightness

should show in a picture, so I hurried down for my camera, but got back too late.

Normally Operation Distortion changes the base of the object very little, often not at all. Here the length of base of the mountain was not more than one-third that of the range, something I have not seen in any other distortion mirage. It is possible that the Cocopah Range was not the object of the mirage at all. There is, a few miles nearer, and in the same general direction, an isolated rocky hill known as Volcano Butte, not much over 300 feet high as remembered, not normally seen even with binoculars. It may have been the object which became a great shining peak. In any event, it was a beautiful show, magnificently staged.

More recently, from the same spot, a slightly similar buildup of Picacho Peak was observed. In this case, only the upper portion of the object was involved; the lower part and adjoining hills were not changed. My drawing (fig. 4) attempts to give an idea of the distortion brought about. The shining whiteness of the extended portion with the sunlight on it was reminiscent of the Fujiyama-like mountain. Radiosonde reports that morning from the Yuma Test Station, some 10 miles east, showed a weak temperature-inversion

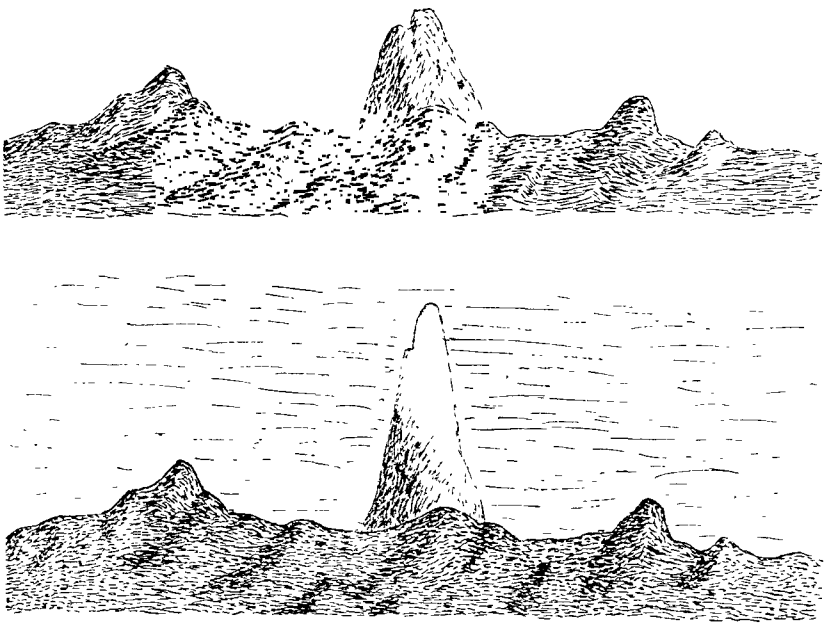


FIGURE 4.—The Picacho Mirage. *Upper:* The normal skyline of Picacho Peak, a precipitous rock mass which rises to an elevation near 2,000 feet, 20 miles north of Yuma, Ariz., one of the annual climbs of California's Sierra Club. The famous Picacho Mine was near its east base. *Lower:* The mirage of Picacho Peak observed about 8:30 a.m., February 20, 1958. The skyward extension was an estimated 600 to 700 feet. Most of the extended portion was shining white. The appearance lasted more than half an hour with little change except for a drifting band of stratus clouds which hid the central portion of the peak much of the time.

layer at about 1,800 feet. To cause this mirage, the layer between Picacho and Yuma must have been fairly strong, with the elevation well over 2,000 feet.

It has been my observation that "mirage showmen" are very partial toward the No. 2 lenses for morning exhibitions and No. 1 for afternoon displays. Generally, too, a brisk wind is unfavorable for formation of a mirage-making lens aloft, having a decided mixing effect. But there are exceptions. One particular production was staged about midafternoon in a brisk 12- to 15-mile-an-hour wind. Scattered desert brush and scrub trees had been assembled and lined up with looming effect to look like a row of trees, as though along a fence or road, 25 to 30 feet high. Looming trees are not unusual, but the scattered, scrubby material the mirage makers had to work with was exceptional. It was a nice-looking row of trees. As an added feature, the lively east wind snatched the west end of the row, two or three trees, and whirled it away 30 to 40 yards where it disappeared in complete fragmentation and instantly reappeared back where it belonged in the row. This happened over and over again as long as we watched. It reminds one of the lens in the road, steadfast in the wind and hurrying traffic. I have had other reports of wind disturbance by No. 1 lenses, but this is the only case I know of for a No. 2.

The following example defies classification: Just across the United States-Mexico boundary in Baja California there used to be a shallow salt lake known as Laguna Salada nearly filling a valley between the Coast Range and Cocopah Mountains. It had long been fed, through its southern end, by high tides from the Gulf of California and overflow from the Colorado River at times of flood, helped by some mountain runoff. A shift of the river channel following a break into the Salton Sea in 1904 silted up the entrance, and the lake slowly dried up in spite of local runoff. Visiting Laguna Salada in 1925, we topped the pass south of Signal Mountain to get an excellent view of the lake bed, dry and dazzling white except out toward the center where there was a little blue body of water. Water is almost always an appealing sight in our desert country, so we drove to the north end of the Laguna, walked down a gently sloping beach littered with seaweed and shells, then dropped steeply 7 or 8 feet to the level floor, intending to walk out. But from there no lake was visible—some strips of what was evidently mirage water in the distance but nothing that looked like real water. Apparently we had been well fooled. Climbing out, there was our lake again. As we walked south along the ridge it was still visible from the pass in the same place and of the same size and shape. Studying it with binoculars, we could see no sign of ripples, but it looked very real. So I left



1. The writer watching mirage on Black Hill, observation point from which Cocopah and Picacho mirages were seen.



2. This is one of the water-in-the-road mirages. The photograph was taken in Yuma, Ariz., by the writer in June 1959. There is absolutely no water in the street.

the others, scrambled down to the shore with the lake still in sight, dropped down to the lake floor—and there was no lake! I walked out toward where it had seemed to be. The surface was a thin coating of white with black alkali underneath, which kept getting softer. I must have gone well over a mile and was sinking over my shoetops at every step. The white surface stretched away ahead without a break as far as I could see, so I turned back. From the ridge we could follow my footsteps, black against the white surface, ending less than a hundred yards from the real lake.

A few hours later we were telling the story to Imperial Irrigation engineers in Calexico. Their comment was, "Of course it was water. People go down there to swim." A few months later I saw our lake from the air. This is rather a reversal of the usual mirage story of seeing water where there was none. We were unable to see water where there was some.

OPERATION LONG DISTANCE

The mirages of Operation Long Distance are the best remembered and the most difficult to explain. It seems best to establish a background of what they do; later we can start trying to explain how they do it. Their job is to make an object seem to be where it is not—not just lifted a little way into the air, but moved a few or many miles away.

In a small Maryland town only one mirage seems to have been seen in nearly a hundred years, but that one is remembered. It showed a city in the sky, a city of domed roofs—foreign looking, not at all American. Judging from appearances, it would seem to have started on its long journey from North Africa or one of the eastern Mediterranean countries. Reaching back fully 75 years is the story of a mirage seen not too infrequently over the Palomas Plain, about midway between Yuma and Phoenix. It has long been known as the mirage of a Mexican city with no attempt to identify it. In 1920 the station master at Baghdad on the Santa Fe Railroad some 60 miles east of San Bernardino told me of mirages seen over a dry lake bed south of the station. He had seen them several times. According to some of the watchers it was the modest city of San Jose, Calif., 500 miles and half a dozen mountain ranges away. Recently an Army sergeant called to tell me of a mirage he had seen some 40 miles northeast of Yuma showing a city set up in the desert close to the head of our rugged Castle Dome range. He watched it carefully for more than 20 minutes and was sure he could recognize buildings that would identify it as San Francisco, even farther away. He said it seemed about 4 miles distant. San Diego seems especially well situated for Operation Long Distance. From two quite lim-

ited areas near Yuma, some 20 miles apart, mirages showing the city of San Diego and its harbor have been reported several times, but not from both places at the same time. Approximately the same picture has been reported in Quartzite, 90 miles north, and from Long Beach, 100 miles up the coast from San Diego. All these city images are set up very low, not much above ground level. There have been mirage showings of ships too, always, for some reason, set well up in the sky. In no case here over the desert have inverted images been shown. While cities and ships seem to be favorite subjects, others are sometimes shown. From a service station in California west of Yuma, motorists reported the appearance of mountain scenery, pine trees, shrubery, all complete, seemingly less than half a mile distant, set up right out in the desert.

Operation Long Distance is not confined to the desert. The Los Angeles Times, some 20 years ago, under a Santa Barbara date line, told of a mirage that brought a settlement on one of the Channel Islands, about 30 miles distant, so close to shore that houses could be recognized and boats seen moving about in the little bay. At St. Albans, W. Va., about 1914, a group of young people were on a hill near the schoolhouse after dark. They noticed a glow in the sky, watched it become the picture of a city on fire, could see the firefighting equipment, the flames, roofs and walls falling in, and people rushing about or standing watching. Next day they learned that the fire had been in Ashland, Ky., about 40 miles away. A friend, who had spent his younger years in North Dakota and thereabouts and had traveled a good deal, said that the only objects the mirage makers seemed interested in in that part of the country were grain elevators. They were seen many times, well up in the sky, and always upside down. Many of us may remember accounts of polar explorers who saw rescue ships in the sky several days before their arrival.

A well-vouched story relates that an airplane pilot was flying in the Yuma area at about 3,000 feet, when quite suddenly he saw directly ahead a Navy ship, so close he could identify it and see the bow wave. A check, I was told, showed that the identification was correct and that the ship was sailing off San Diego at the time. Even if the pilot had been interested in mirages, I suppose he would have turned off his collision course instinctively, and lost sight of the ship in seconds, but it would have been tremendously interesting if he had crashed through the mirage picture to find what he would see on the other side.

Sometimes both erect and inverted images are seen, the erect one higher in the sky.

A great deal of material has been published on what Operation Long Distance does, but no article of my reading had even attempted to tell how it is done. This is not a matter of one problem but of many, the most impressive being, doubtless, that of transportation.

How is energy, in the form of the light carrying the picture or image, conveyed through the atmosphere for great distances with no apparent loss of potential? The city or ship that looms so large has not been magnified by any telescopic effect. As nearly as we may judge, it simply failed to get smaller with distance as one would expect according to the laws of physics. Its light power faded little if any, which seems to present an irrational situation. That is what will need to be explained. Two rather fantastic suggestions are offered, very tentatively. One is that there may be channels of no resistance in the atmosphere along which such a shaft of light may travel intact, without dissipation. I am told that the Navy has trouble with radar beams being deflected from a straight course, probably by atmospheric conditions as occurs with light beams; also that radar beams seem sometimes to find channels of no resistance and reach many times their normal range. We know that radiobroadcasts will sometimes be heard at amazing distances, possibly by bouncing from layers in the upper atmosphere or, it is possible, by finding a channel of no resistance. The other suggestion may seem no more realistic. Is it possible that a shaft of light, perhaps traveling in parallel beams, might be so compacted by a cohesive force, like the lens in the road, that there is no dispersion? In either case the paths would run approximately parallel with the earth's surface. Neither suggestion takes into account the inverted image unless it may be formed by secondary refractive action.

As a basis for either one of these suggested possible explanations, some form of No. 2 lens must be presupposed which would be able to pick up the picture and put it into a roughly horizontal course instead of returning it to earth as is the more usual procedure. Apparently it would travel in such a course or channel until it struck a second No. 2 lens where refraction should turn it down to the observer or observation area. This explanation would call for the refracting air lenses to be a few hundred to several thousand feet above the ground near the point where the mirage is to be seen. Why city mirages are so much lower than those of ships is far from clear, but this seems to be true over the desert country.

Just what is it we see when we look at a mirage? Referring back to the No. 1 lens, we seem to see water in the road or dry lake bed. The picture or image is in effect projected on the air lens much as a picture in the theater is projected on the screen. The mirage is just as far away as the lens is. This is not true, however, for the Operations Liftup and Distortion. The mirages turned out by both of these types of lens activity appear to be at their true distances, but lifted up, or lifted and distorted. We get no impression of the location of the lens at all. But for Operation Long Distance we go back to the No. 1 lens type of procedure. Location of the second lens is the loca-

tion of the image or picture. I have a strong impression that on leaving the second lens the light shaft carrying the picture is no longer in any channel of no resistance. Its path is apparently a slender funnel set up by the angle of refraction. Loss of light power and size of image would seem to be proportionately less than if the picture were broadcasted, as from a picture screen.

A ship in the sky may show us such a projection. The pilot who found himself running head-on toward a Navy ship at an elevation of 3,000 feet may have been just cutting into the light beam of the mirage close to the lens.

In the case of the repeatedly seen mirages of the city of San Diego, the image is picked up at sea level, carried over a 4,000-foot-high mountain mass, and brought down again to near sea level some 150 miles away. Elevation and location of the first lens are unknown; those of the second lens may be guessed at, although not too accurately.

Two of my Operation Long Distance mirage stories fail to fit in with the explanation offered. Reports of both the San Jose and San Francisco mirages place the observer between the object and the mirage, seeming to call for something like total reflection. In most other cases in all classifications, the mirage is shown between object and observer, where it would appear to belong. Either the observers were mistaken in identifying these two cities, or we have another unsolved problem. Perhaps under the same problem classification belongs the apparently reliable story told me by a man living some 12 miles south of Yuma. He said he had repeatedly seen a clear mirage of the city at about the right distance to the east.

CONCLUSION

In conclusion, I should like to emphasize that in dealing with this fascinating subject of mirages, even statements of seeming fact have been based on a very limited amount of material, largely of my own gathering, for the more puzzling mirage forms are so rare that no one man is likely to have seen more than a few of them. The most valuable contribution that I could hope to make in presenting this nontechnical article, with its tentative suggestions as to the explanation of certain unusual types of mirages, is the stimulation of further investigation of the whole subject.

Lessons From the History of Flight¹

By GROVER LOENING

*Member, Advisory Board
National Air Museum
Smithsonian Institution*

[With 7 plates]

TO DERIVE LESSONS from the history of flight, we must go much further than merely to list historical achievements. We must delve into a questionable hindsight area to find our mistaken trends—plunge into the jungle of misfits, false starts, and abandoned hopes—picking out on the way the waifs that we have lost and let them give us guidance more clearly to see the mistakes and omissions that we are, somewhat unthinkingly, engaged in today.

At the outset of this study, let us limit ourselves to aircraft and their flying and to related aeronautics, and not get involved too much in the newer area of missiles and space. The latter fields have more strictly to do with artillery and astronautics, except for the brief time of takeoff and landing, and little to do with the air ocean as we know it. Space-missile astronautics has to do more precisely with ballistics in non-air-breathing media.

The aircraft industry itself is almost unconsciously growing into an arsenal and artillery industry, and we can well pause and question whether the romance of the brilliant and exciting things that are being done in the space field are about to dull our realization that heavier-than-air aviation still is, and will be for a long time, a great field of human endeavor, of transportation business, and of military logistics activity on a huge scale.

The growth of the U.S. air-transport industry from nothing in 1920 to 24 billion passenger-miles in 1958 is merely a beginning. We will shortly progress into supersonic flying all over the world. Europe-in-an-hour, round-the-world-in-8-hours, are on the drafting board. In a few short years both fields, aircraft and space, will, however, outgrow the present flurry of incorporating them into one pack-

¹The Lester D. Gardner Lecture, given originally at the Massachusetts Institute of Technology, and given also at the Smithsonian Institution on May 18, 1959.

age, and probably there will be a change of setup in which they will spin apart, in order not to retard or interfere with each other.

There is, then, much left to do to perfect our utilization of the air ocean in which we live. Tolerable levels of noise, vibration, and acceleration must accompany supersonic flight. And greater safety! These are all of utmost importance to our great air-transport development, but have little to do with space astronautics.

Some clear and not too pleasant lessons are to be learned from a questioning and reflective perusal of the more than half a century in which we have developed our air travel, air logistics, and air road-to-everywhere usage. One of the most outstanding lessons that we see clearly in such a review is how often designers and constructors have failed to finish what was started. Owing too often to discouraging initial troubles and "bugs"—often added to by lack of foresight and interest on the part of the aircraft customers, military, industrial, and civilian—the continuity of effort for success frequently has died on the vine, with the result that needed and highly desirable developments that had been started were abandoned and lay dormant, only to be revived years later.

Many a novel but highly significant development, idea, or suggestion has lain on our doorstep for years, unappreciated. Let us look at a few examples:

WING STRUCTURE

In America, where flying was born, the biplane type of flying machine dominated our efforts from the very start for almost 25 years, despite the obvious success of the monoplane in France and the fundamental correctness of its aerodynamics. Today the monoplane, strut braced or cantilever, has completely swept the field in all types and sizes, and the only biplanes left are occasionally seen towing an advertising sign or doing some crop dusting.

The Junkers low-wing cantilever stressed-skin all-metal monoplane, after its 1920 development in Germany, was brought over to this country and promptly ignored. We recognized only vaguely a few years later that it was being used very successfully on the first great Western-world airline, Scadta (later Avianca), up and down the Magdalena River in Colombia. Even in 1923, when the Loening amphibian was being developed, we had to abandon the monoplane temporarily in order to sell our design to reluctant aviators by making them feel at home in a DH-4-type biplane wing. Through the rest of its life this airplane was 200 pounds heavier and 15 m.p.h. slower than if it had been a monoplane.

It was not until William Stout developed the Ford planes some years later that we moved seriously into the stressed-skin metal monoplane structure. Fokker, during these early twenties, also chose the

cantilever stressed-skin monoplane, but used plywood covering, which could not take the weather.

LANDING GEARS

In earlier years, landing gears had skids to which wheels were added, but the skids were the cause of many wrecks when they broke on hard landings. From the very beginning, wheels alone were obviously correct. In Europe, Bleriot, and in America, Curtiss, were alone in realizing this, and in the case of Curtiss we must recognize that the practical three-wheel gear was constantly being demonstrated as successful and correct by the early Curtiss planes, but practically no one else saw this. Even Curtiss gave it up about 1915. The advantage of being able to land and take off in a cross wind was lost. And yet some 35 years later the three-wheel gear with level fuselage configuration came back into practically worldwide usage. Brakes on wheels were suggested at an early date, but the majority of the air industry scoffed at the idea because to them it was only too obvious that applying the brakes too strongly would turn the plane over. So a few feeble braking features were used on tail skids.

Then came the question of retractable landing gears. The desirability of these should have been obvious at the earliest date at which we reached 100 miles per hour, which was in 1912. But history shows that it was the advent of the successful amphibian plane (which had to have its landing gear foldable) that taught the lesson that retracting a landing gear and housing it were neither too complicated nor too heavy. There had been several successful landplanes with folding gear, notably the Verville monoplane of 1922. Nevertheless, it was some 6 or 8 years before retractable gears came into more general use.

PROPELLERS

Variable-pitch propellers were suggested at an early date—a practical one by Hamilton in the twenties—but it took 8 or 10 years for these to come into wide and general use. Incidentally, even the advent of the metal propeller so competently developed by Sylvanus Reed, after solving forging difficulties, took far too much time for acceptance.

ENGINE PLACEMENT

On the early configurations in America, engines were to the side of, or behind, the aviator. In the case of the original Wright design, the translating of 12 horsepower into effective enough thrust to fly 750 pounds required the two large geared-down propellers—and, in fact, this was one of the secrets of the Wrights' success. As more powerful engines came along, such as Curtiss's motorcycle engine, the gearing down was not needed, but the engines remained behind the pilot.

It is curious that this arrangement should have persisted in this country, when in France the great early pioneers, Bleriot and others, from the start had tractor-type monoplanes, although some other earlier constructors like Farman and Voisin also used pushers. But the tractor type in France was more numerous, in the Santos-Dumont "Demoiselle," the Nieuport, and the Breguet, Ferber, and Goupy biplanes.

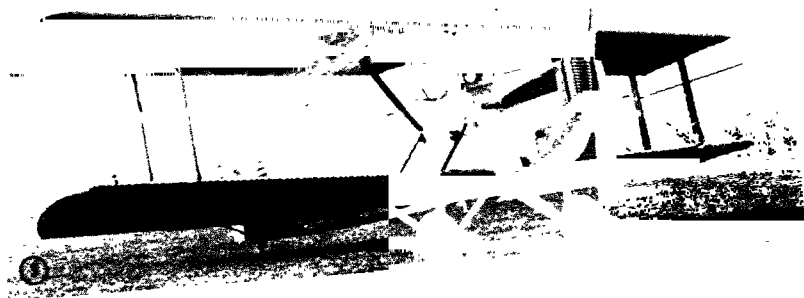
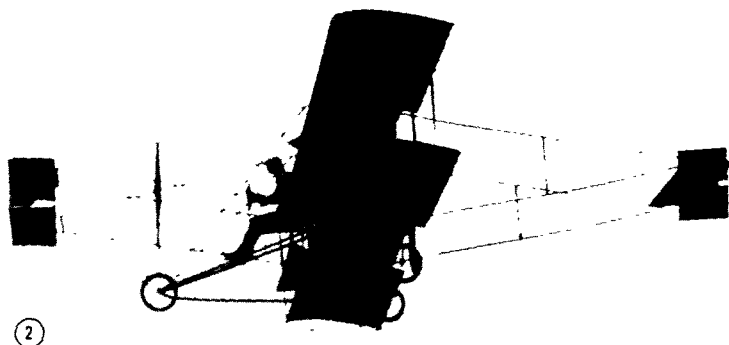
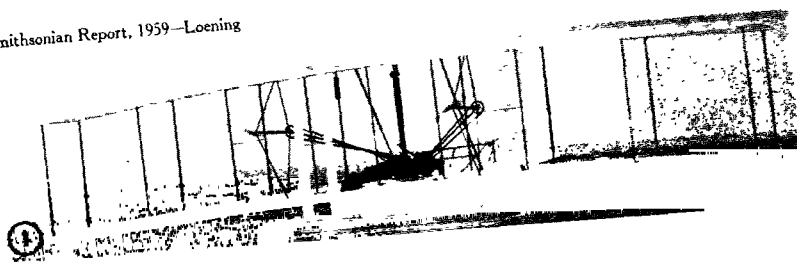
In this country, it was not until 1913 that we saw the Burgess tractor with Renault motor, the Glenn Martin Model TT, and the Curtiss N which later became the ubiquitous JN-4 (the Curtiss Jenny). So, as far as the general industry is concerned, we see that we here lagged 4 or 5 years behind in adopting the tractor-type airplane which was to become practically universal as a landplane, even when later developed into multimotor models.

ENCLOSED BODIES

Safety in crashes was naturally the outstanding reason for the adoption of the tractor type. In the early planes, when they were in the 40-mile-per-hour category, the seats were not enclosed. The advent of the fuselage with enclosed seating was stimulated, of course, by the use of the tractor engine. But it is remarkable to note that the obvious further streamlining and closing in of the fuselage lagged for a few years. Nieuport, in his remarkable and revolutionary little monoplane of 1910 which swept the field in competitive performance, practically started this vogue. But the enclosure of the aviators themselves in a cabin was very slow in coming, and it was not until some 10 or 15 years later that the majority of the aviators, including the military, discovered that they need not have their heads out in the open air in order to fly, and permitted their definite prejudices against closed cabins to give way to the comforts that became immediately evident.

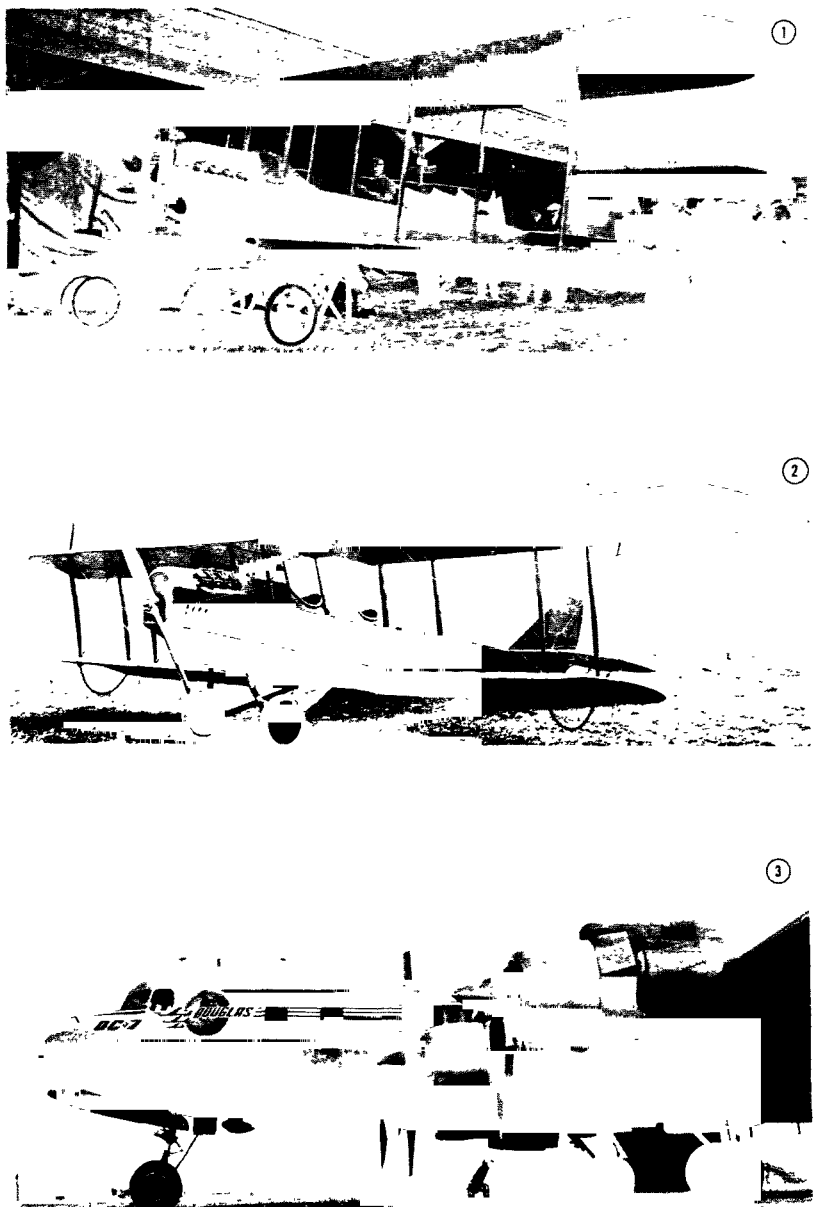
HIGH-LIFT DEVICES

Flaps and slots to slow down landing speeds, or rather to permit higher cruising speeds and heavier loads without too great a landing penalty, also lagged for a long time—much too long. Handley-Page and Lachmann in Europe and Orville Wright in this country were investigating these high-lift aids in the twenties. In fact, it is not generally known that Orville Wright in 1923 patented the split flap. By 1926 Handley-Page slots had been applied to the British "Moth" plane with great success, and the first such "Moth" to be imported to this country was brought in by the present writer and flown by him widely in the east. Still, a great many airplanes were being built, developed, and accepted with no thought of high-lift devices, although some work was being done, notably by Harlan Fowler, on these additions to wing structures. Then, in 1929, was held the Guggenheim



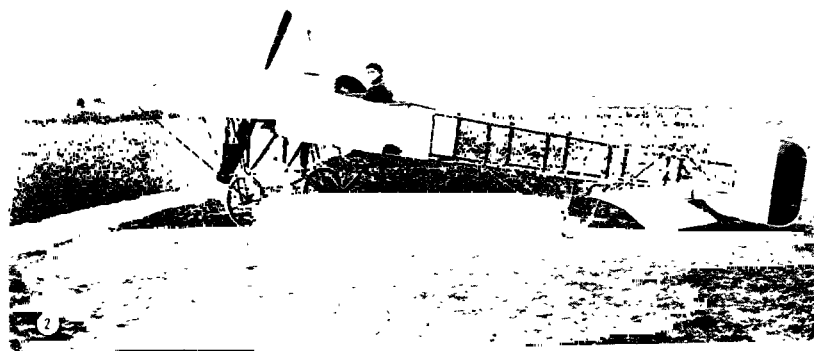
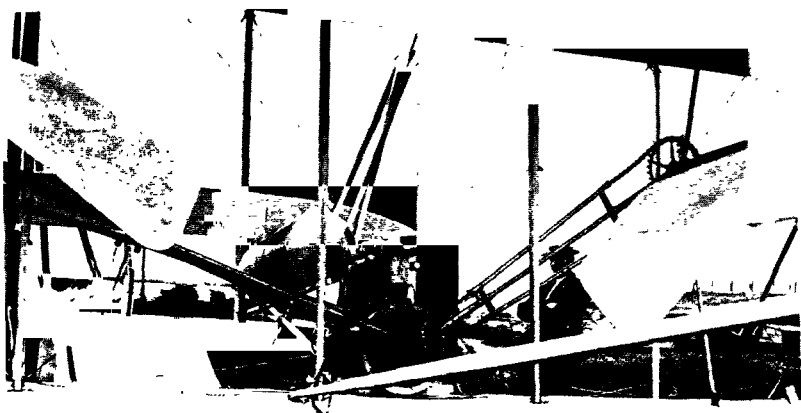
TYPICAL EARLY BIPLANES

1. Wright brothers' "Kitty Hawk" biplane, the world's first successful powered and controlled man-carrying airplane, 1903; 2, Curtiss biplane with pusher engine, 1908-1910, showing classical landing gear to come into wide use 50 years later; 3, Douglas World Cruiser, typical tractor biplane, 1924; 4, Loening amphibian biplane, Pan American flight, 1926-27.



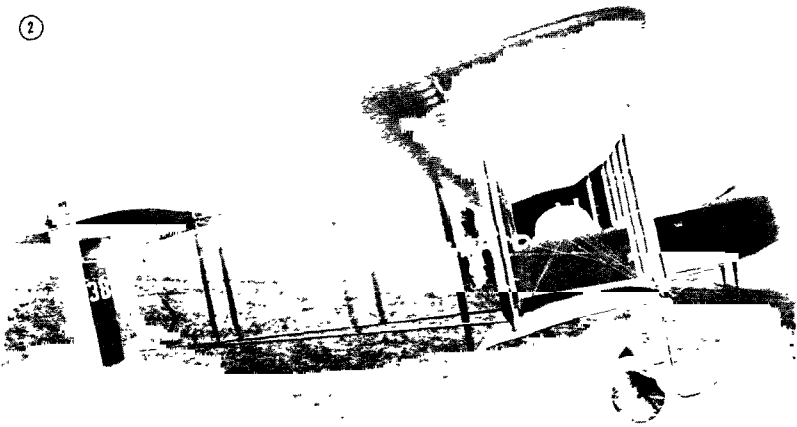
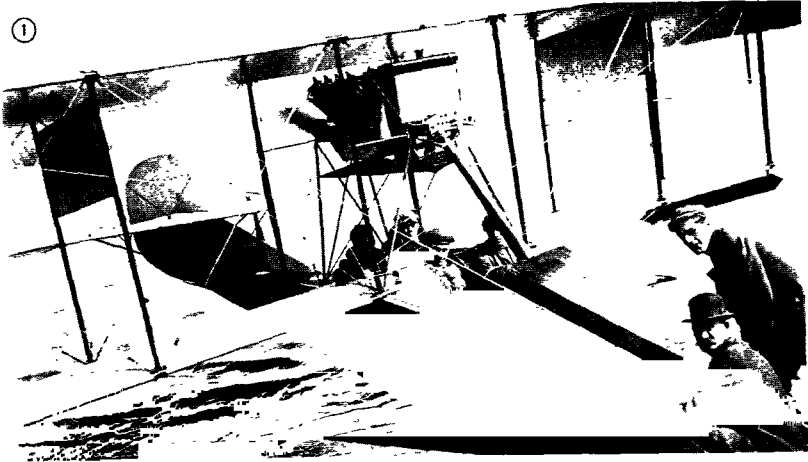
LANDING GEARS

1. Martin-TT, tractor training plane, 1915, showing cumbersome landing gear with extra wheels and slids; 2. Curtiss JN4 ("Jenny") training plane, 1918, showing simple 2-wheel landing gear which later came into world-wide use; 3. Douglas DC-7B of 1935, showing classical gear-level aircraft position used widely on modern air transport planes.



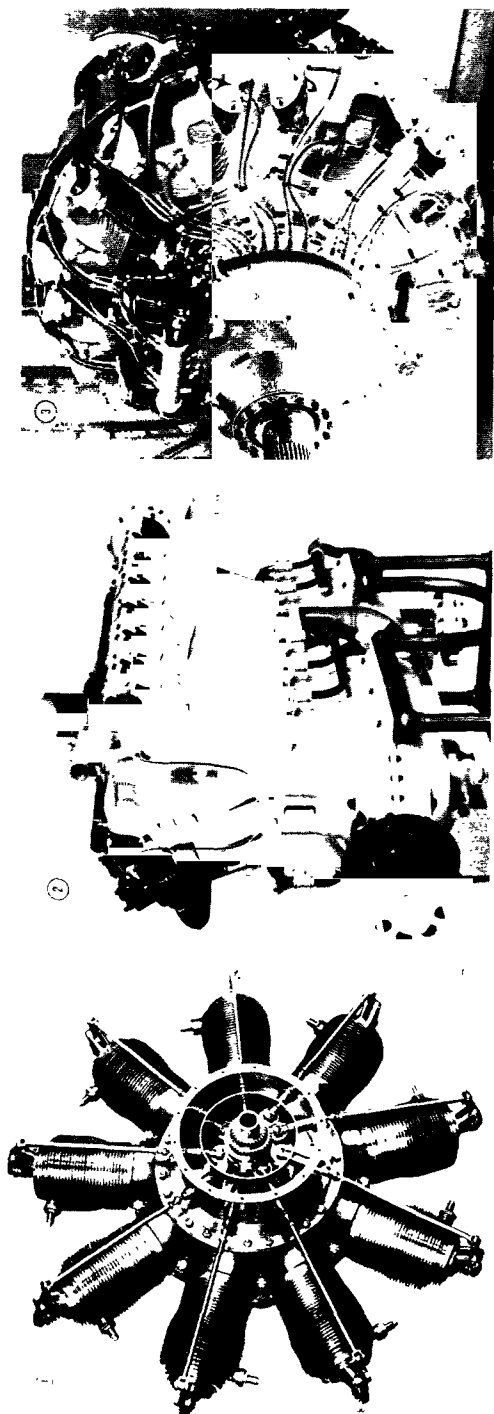
ENGINE PLACEMENT

1, Wright biplane, Fort Myer, Va., 1908, showing engine mounted on wing to the side of the aviator; 2, Bleriot monoplane of 1909, with tractor (in front) motor position.



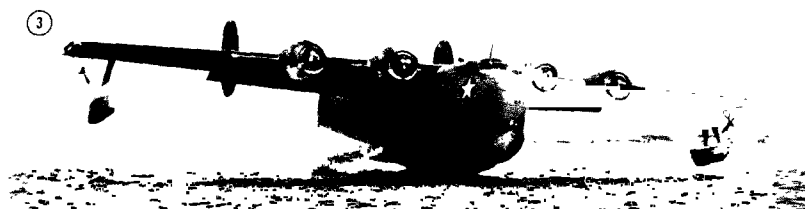
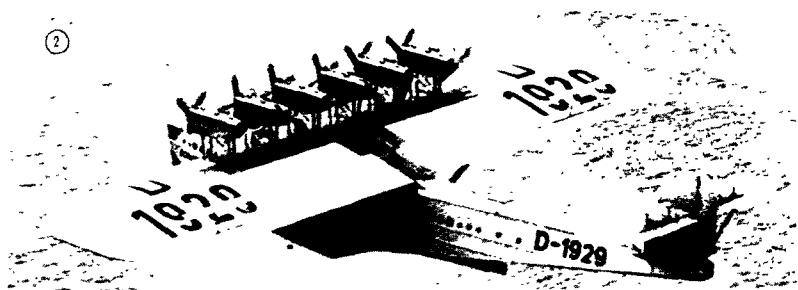
ENGINE PLACEMENT (continued)

- 1, Curtiss pusher flyingboat, 1913, showing engine behind pilot and above cockpit;
- 2, Farman pusher biplane, 1915, with Gnome rotary engine, representing the highest development in France, at that date, of this type.



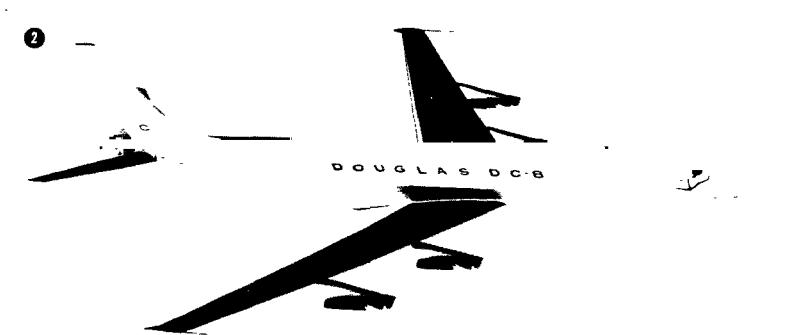
POWERPLANTS

- 1, Chrome rotary engine, 1917, widely used, particularly in Europe, by many types of aircraft; 2, 12-cylinder Liberty engine, 1918, the final successful product of America's World War I enterprise; 3, Wright "Cyclone," modern 18-cylinder radial aircooled engine of World War II.



BOAT-SEAPLANES

1, NC-4 Navy 4-engine seaplane, first to fly across the Atlantic Ocean, 1919, engine location between biplane wings; 2, Dornier DO-X transoceanic flyingboat, 1929, with 12 engines placed on top of the strut-braced monoplane wing; 3, Navy Consolidated "Coronado" type flyingboat, 1942, the general configuration in wide use in air transport as well as in the Navy from the mid-1930's to the present time.



CURRENT JET TRANSPORTS

1. Boeing 707, pioneer 4-engine jet transport, showing engines mounted close to ground under wing; 2. Douglas DC-8 jet transport in flight, landing gear folded, jet engines equipped with sound suppressors; 3. the Caravelle, French jet transport which pioneered the correct location of jet engines (high and aft), a type now coming into much wider usage.

Competition which was specifically designed to advance and encourage airplanes that could land in smaller fields over obstacles without sacrifice of useful high speed. This was the real beginning of the STOL² in this country.

The winner of that competition was the Curtiss "Tanager," a very intelligent design that made full use of the then-existing high-lift devices. Did all aircraft, the year following, adopt split flaps, or Fowler flaps, or Handley-Page slots that had been so successfully demonstrated? They did not. There was the usual opposition, criticism, and delay for several years more before this highly desirable development in aircraft wing structure came to its now universal fruition. A fine recent example is the Helio-Courier.

POWERPLANTS

Let us look for a moment at the history of the development of aircraft powerplants. The Wrights designed their own engine for their own aircraft, and for its purpose it was correct. In France, in the earlier days, most of the early powerplants were derived from automobile or motorcycle sources. The first plane to make an officially recorded flight in Europe, the Santos-Dumont "14-bis," used a 50-horsepower, 8-cylinder Antoinette motor. But it was not long (1909) before the French had developed the Gnome rotary air-cooled motor which in ever-increasing sizes and improved types took over the field for several years and saw very wide use in the First World War. In this country, Curtiss continued to develop his original motorcycle engine into a series of aircraft engines, such as the 90-horsepower OX-5 and others of even higher horsepower. Then came the Liberty motor development, while in Germany there was wide development of water-cooled automobile-type upright engines of this character.

Very little thought had been given to the fact that whereas in an automobile it is desirable, in fact mandatory, for the crankshaft to be low, in the case of the tractor-type airplane it was highly desirable for the crankshaft to be high, so as to provide propeller-tip clearance, to keep the center of gravity low, and enable the pilot to see over the engine. It was not until 1924, however, some 15 years after the Curtiss and Wright engines, and later the Hall-Scott and the Liberties, had gone into extended use, that we in America finally saw the light on this and inverted the dry-sump Liberty engine, thus placing it in the configuration in which it should have been all along. Except for its successful use in the Loening amphibian, this development came almost too late, because it was shortly succeeded by the radial air-cooled engine that developed to such a great extent from the original pioneer work done by Charles Lawrance, the designer of Lindbergh's Wright "Whirlwind" engine.

² Short takeoff and landing.

SEAPLANES

Our seaplane problem largely involved engine and propeller location troubles. Engines were placed in hulls, overhead, behind, and of course outboard on the wings as well as in tractor configurations. A cumbersome configuration of inefficient design was the Dornier DOX, which was built only once. Present-day jet engines have a much wider choice of location because of their light weight and because there is no propeller-clearance requirement.

MATERIALS OF CONSTRUCTION

Materials of construction of aircraft have gone through many cycles. Starting with wood, fabric covering, and wire or cable bracing, there soon arose (with Fokker and Esnault-Pelterie in Europe and Sturtevant in America) a trend to metal-frame construction, either structural sections or steel tubing, brazed or welded. For several years after the war, and in spite of the Zeppelin Duralumin development, aluminum was suspect as a structural material—so much so that the famous Specification 100-A of the Navy prohibited the use of aluminum in any structural part of aircraft. This is a pertinent example of how too-rigid specifications, based on what was good practice in previous years, can prevent future development.

Today we face a similar situation in prohibitions against Fiberglas or plastic-stressed structures because it is so difficult, theoretically, to calculate and check the stressed condition. Yet plastics may well have as great a future in aircraft structures as dural stressed-skin monocoques and wing panels had 30 years ago. We hardly need to recapitulate how metal took over from wood, replacing a material that could not stand the weathering difficulties of day-in, day-out air operation. New alloys—titanium and others—are beckoning alluringly, like Fiberglas, for a chance to show their worth. Also, “sandwich” materials are most promising. Will we still be slow to accept new developments?

WHY THESE DELAYS?

What is the reason for these long delays in acceptance? The lesson one seems to gather from the instances cited and many others is that aviators' likes and dislikes have been given too much weight, thus discouraging the engineers from perfecting their developments. In retrospect, one finds many instances where worthy developments were ignored or abandoned. Many a wing flutter that scared a test pilot condemned to utter oblivion an airplane that had structural or configuration features of great importance and advantage. Had the customer and the builder been patient or wise enough to work out such “bugs,” success would often have followed.

On the other side of the picture, many an airplane with little commercial or military value was for years accepted because the upholstery and the windshield were well worked out, and because a lucky combination of slipstream and wing flow (totally unforeseen by the designer) gave unusually good control on landing which made it easy for the pilot.

AIRCRAFT OPERATION

Let us now look at today's aircraft operation for further lessons and possibly anticipate some future troubles, particularly as to safety. Today all aircraft can be spun and recovered with safety; 40 years ago, this was not so. Up to 1913 the "spinning nosedive" or the deadly "spiral dive from air pockets" was the disheartening cause of accident after accident. At Dayton in 1913 came a very important historical turning point in airplane operation. This was when Orville Wright, discouraged by the accidents that were happening to his exhibition fliers and to a whole series of Army fliers (Hazelhurst, Love, Kelly, and many others), determined to test out himself what was happening. It was not long before he came back from these test flights smiling instead of grim, because he had discovered what a "spin" is, and how to get out of it—by pushing forward on the controls; and why so many aviators had been killed—by pulling back on the controls at the wrong time, instead.

Now, some 38 years later, when we begin to fly through the sound barrier, we discover that there is a brief moment when controls are reversed. And also today we are plagued by "pitchup" in the control of supersonic aircraft. Recently a jet airliner suddenly dove 29,000 feet. Are these effects the manifestations of some new operational characteristic of sweptwing aircraft which may require some additional or different controls other than the ones we have provided?

The operation of aircraft has become very complex, owing to the constant addition of more and more instruments and more and more traffic controls. We have gone a long, long way from our first instruments—the waving string for sideslip, wire whistling for speed, and the railroad track for navigation! Are our present instruments really the ones we should have? Has not the barometric altimeter caused us so many accidents that we should long ago have gone to something better? Our automatic pilots are all based on known flying procedures. Perhaps the new types require some new flying-control procedure, such as crossed controls to prevent "pitchup" or to prevent the sweptwing dive.

It is in such areas that we are much too complacent and that we leave lying on our doorstep, without enough concern therefor, problems that should alert us more quickly to determined inquiry. In 1917 Lawrence Sperry invented and demonstrated the turn-and-bank

indicator. In 1934 the Army took on the airmail. Their planes did not have the turn-and-bank as did the civilian planes. This one regrettable oversight was such a serious factor in causing tragic accidents that the cancellation of the Army's effort followed, largely, when reviewed, because of this.

The complicated procedure now required for flying is becoming so expensive and cumbersome that private-owner flying will soon become as impractical as owning a private locomotive. The airlines and the military seem to aim at making the free airspace a monopolized railroad track. Will not this trend throttle our greatest future segment of aircraft manufacturing—the air-vehicle industry to succeed the automobile? This must not be allowed to happen.

NOISE

Noise abatement is now clamoring on our doorstep, but we should learn from our history that abatement itself is not now the answer. The answer is to design a powerplant with as much consideration given to a fundamental limit on noise in its original design, as is given today to its fuel consumption and weight. We can soundproof against internal noise rather well in a cabin, but external noise has made the airplane a very undesirable neighbor, even to the extent of having it ruled out in many places, and high-pitch vibrations are now being suspected of causing structural failures. Have we, through these formative years, appreciated noise problems enough? This one can be answered quickly: we certainly have not.

AIRPORTS

Literally billions of dollars are being spent on airports throughout the world. In too many instances, particularly in America, these have only one runway—in other words, they are like a one-track railroad. It is difficult to understand why this is so, when we stop to remember that during World War II whole squadrons of aircraft landed on and took off from runways wide enough to permit several airplanes to take off or land at one time. In these operations the aircraft were within a few feet of each other. Why then should not a commercial airport have at least three runways in each direction, spaced possibly 300-feet apart, center to center? On such areas we could then proceed to land three aircraft at the same time, or at least be landing aircraft on one runway and having others take off on another simultaneously.

The hesitation on this is typical of our complacent thoughtlessness. There is no danger involved. Thousands of times a day the pilots of large transports land their planes accurately and within a few feet of the centerline of runways, and never run off into the ditches on the

side. To be sure, in close navigation in heavy weather we do need to know if another plane is near us, but it is within the power of radar instrumentation today to supply aircraft with close-proximity radars, possibly even with a television connection that would show up anything in the immediate vicinity. Radio, of course, has helped tremendously to bring about the era of practical civilian flying, and it can be counted on to continue to give us the things we need now if we will but indicate the required elementary development—simple, close-reading radar with 2-mile radius to begin with, not 200 miles—direct-reading radio altimeters, with 200 feet radius, not 40,000 feet. We have been demanding too much all at once of these instruments, with the result that we have little as yet.

THE JETPLANE DEVELOPMENT

The jetplanes of the day in America are not being developed in the same way as they are in Europe in one particularly important characteristic—the location of the jet engine. The Douglas DC-8 and Convair 880 have followed the lead of the Boeing 707, which naturally followed the lead of the B-47 and the B-52. Unfortunately, these leads seem to derive from the old position of piston engines in nacelles mounted outboard on the wings. Here we have a very typical illustration of a lesson not learned from the history of our art. For a jet engine there could not be a more questionable location. Jet engines are very light, so that the structural saving of spreading the weight over the wing is very much less than in the case of the piston engine. Also there is no propeller clearance requirement. But the engines are now located so low that they will ingest any loose material on the runway with great risk to the delicate turbine engine interiors.

The outboard engine is so low that a tire or wheel failure on one side could break it up on the ground, followed possibly by fire from the gas tanks above it. The position of the engine under the wing makes the wing a perfect sounding board to disturb the neighbors below, and the inboard engine is so located that its noise cone hits the rear of the fuselage, making it an almost untenable position. The builders and operators are fully aware of these features and are of course doing all they can to assure us maximum safety.

But in Europe, most of the newer commercial designers completely separate themselves from all piston-engine concepts by placing the jet engines where they belong: above the wing and to the rear, mounted to the fuselage and leaving the wing with perfect aerodynamic cleanness. Maintenance also is improved by this location. VTOL³ concepts mentioned below may soften the impact of this questionable American design. Let us hope they do.

³ Vertical takeoff and landing.

THE LIFTPLANE—VTOL

The biggest revolution in the coming design of useful aircraft will be the advent of the direct-lift airplane, sometimes awkwardly called VTOL. After some 10 years of intensive research, resulting in several bookshelves full of excellent NACA and other laboratory reports on how to make a fast airplane land vertically, it is only now that we are beginning to show the needed interest and the start of progress in this development. Boundary layer control is only one facet of the problem of landing vertically. Tilting wings, tilting jet engines, and other ways are being developed.

The helicopter is not quite the answer, simply because its speed is limited owing to the rotor configuration. Even if helicopters get up to a high cruising speed of 200 miles per hour, they will still have to compete with fixed-wing aircraft of over twice that speed. Throughout the history of aircraft development, there is one lesson that stands out clearly: high speed is always the successful characteristic of any type of operation, even on the shortest ranges. Slow aircraft, no matter for what purposes, have never survived.

On the other hand, the airplane as we know it is a very deficient vehicle because it cannot slow down, hover, or back up, as every other vehicle can do. The penalty we pay for this characteristic of having to keep going in order to stay up is great. More skill is needed in operation. Prepared airports must be provided, running up now to preposterous 10,000- and 15,000-foot-long runways, using up an amount of real estate that drives the airport to a distance from the city. So many planes want to land at the same one-track airport at the same time that very complex traffic-pattern and traffic-control problems arise. For jetplanes, as much as 100 square miles of airspace must be reserved for each plane while it awaits its turn to land on the one-track airport. All this because they cannot slow down below 180 m.p.h.!

Many objections to liftplanes (VTOL) are now being voiced. One is that the fuel consumption for vertical flying is utterly prohibitive. In the light of history, this objection belongs with those that were initially raised to monoplanes, to metal construction, and to slots and flaps. A simple analysis will show that while direct-lift by jet will need three or four times the thrust of the existing jet-engine configurations, and will therefore use three times the fuel, the actual fuel used by the jet transport in taxiing out to the end of a long runway, waiting for clearance, the long takeoff run, then climbing to 1,000 feet, is almost as much as the direct-lift plane would use rising immediately to 1,000 feet from its pad at the loading ramp, with all engines full-out, and then shutting off its lift engines.

Another objection in the same class as the earlier ones mentioned above is the weight of the extra jet engines for vertical thrust.

Actually, vertical lift capability means a much lighter landing gear, which might almost revert 57 years to the Wright skids, leading to an aircraft with practically no landing gear at all except little rollers to push it around the ramp. Thus the weight of the extra jet engines that are needed for the vertical operation could be compensated for and would represent no more of a burden to the aircraft than did the landing gear. Originally, this represented 6 to 10 percent of the empty weight of the aircraft, was used only for a short while on landing and takeoff, and was carried neatly folded in precious room in the body for thousands of miles during which time it was utterly useless. On the other hand, the extra jet engines could, in an emergency, be used if the other powerplants failed, or for quicker climb. And with the ability to rise vertically and fly fast, the liftplane in smaller sizes, if not too noisy, would at last penetrate the open and fertile field of private vehicle aircraft, which has hardly even been touched, although we now lead the world in this field.

When we come to the future supersonic transport with speeds up to 2,000 m.p.h., where more thrust from the engines will be needed than the whole weight of the aircraft, their design could begin now with a VTOL configuration. When we contemplate many different designs of aircraft for vertical lift and high speed, we find that the gas generator (the jet-engine powerplant) will most likely become a very intimate part of the wing. In fact, the final requirement of the gas generator is for a forced lift flow around the wing, including boundary layer control. For the slow-speed regime, a large volume of air moving more slowly (400 m.p.h. or so) is used and then replaced, when once up in the air, by a suitable change in ducting to the high-speed "thrust" flow that we use today over a small cross section for fast aircraft. The wing then may well become the crankcase of the engine!

In 1926 Henry Ford, Sr., visited an aircraft show in Detroit. As he was leaving, he turned and looked over the planes and said, with his usual finality and quickness: "Let me tell you, these things will never amount to anything until they use their power to land with!" History will show that he was right.

OTHER LESSONS

Many other lessons are to be learned from the numerous aspects of our broad aeronautical field. The Zeppelin airship had its great value in bringing us Duralumin. Developed originally in Germany, with a courageous persistence through many discouragements, and with later developments in England and America, the large rigid-structure dirigible airship did not survive, even after helium made it really safe. The reason was not structural. It had only one disadvantage—it was too slow. And the lesson is this: In air logistics,

whether it be military or commercial, it is the load carried per year and not per trip that spells success. The aircraft, no matter what type, that carries less ton-miles per year per crew cost, or per pound of fuel, or per horsepower, finally loses out because it does not make enough trips per year.

We are becoming aware that speed is the *raison d'être* of flying, particularly in transportation of passengers. Have we learned that the greatest comfort of all to a passenger is the notice that he has arrived? A supercomfortable seat does not balance a tediously slow aircraft.

We must also consider the seaplane and realize that it is all but lost today. Propeller clearance from the water limited early seaplanes because the configurations required an awkwardly high engine location, or a deep hull, or bulky pontoons. All this weighed more than a simple landplane and had more parasite drag, which adds up to more slow-speed deterrent. Also rough water kills the seaplane as a boat. Even the largest seaplanes we have had, some over 100 tons, are still a mighty small boat with which to tackle the ocean, particularly when the slowest speed on the surface for landing or takeoff is as prohibitively high in open seas as 50 to 100 knots.

The jet engine, however, is apt to change this picture very greatly in the next decade. To begin with, the propeller clearance parameter is done away with. A seaplane's aerodynamic forms can now rival those of the landplane, and because a seaplane alights on its hull on the water, weight and complications are saved by elimination of heavy wheeled landing gear.

But the seaplane would still have to contend with rough water, were it not for the imminent advent of VTOL—vertical takeoff and landing, which will eliminate the “rough water blues”! In fact, the readiness with which several new helicopters have acquired amphibious characteristics, merely by a watertight fuselage, is a revelation. Settling on the water, even when very rough, is no trick at all. And water surface is perfect for vertical-thrust slip-stream takeoff—no dust, and fine ground bank.⁴

We need a waking-up here, because water surface, so widely available near where we want to go, is free real estate! Also, the seaplane or water-based airplane leads more readily to the real giant aircraft (1 million pounds load, and 600 m.p.h. speed) which would be too heavy and impractical if a retractable landing gear with wheels had to be provided.

CONCLUSION

In concluding this incomplete review, these are the lessons we should learn:

⁴ The extra-lift “bounce-off” effect experienced when close to the surface.

Right under our noses, today, are wrong trends, unrealized, and right trends, unappreciated, because we do not think things through enough.

The turbojet engine (except perhaps for a few metallurgical elements) could have been built and used 30 years ago. And why did this not come about? Because at that time we were thinking in terms of 100-mile-per-hour aircraft, and any designer would have known that the fuel consumption was prohibitive. None of us realized then that jet engines immediately meant 600 miles per hour. And so we missed it. We could quite quickly have learned how to handle high-speed flutters and drags.

Are we too complacent in believing that engines and airframes are separate entities? Reviews of aircraft design clearly show how much time and cost were consumed in trying to fit existing engines into airframes that were never designed for such engines. The two are, after all, a unit and, with the advent now of vertical flying, airflow requirements around a wing from the jet engine gas generator source make the wing construction an intimate part of the powerplant.

A breakthrough on lighter radiation shielding is now imminent, and this means nuclear powerplants. So let us start our thinking on this new type at once in terms of wing flow and low noise level.

As to research, our history shows that we may, at times, overdo it. Scientists find the hardware-in-use stage less pleasant and are therefore reluctant to reach it too soon. This type of block needs a fine judgment and considerable prodding from the user-to-be. Also, occasionally we have been too slow in realizing that wind tunnels are not always the final answer to research. In supersonic aerodynamics, in particular, many correct results can only be found in the open air, free of restrictions, giving the correct ambient flow, accelerations, etc.

In only 50 years of air transport we will progress from the remarkable Sikorsky pioneer 4-motor cabin plane of 1913, to the coming supersonic VTOL transport of 1963. World history seems to show that anything man can clearly imagine eventually materializes into reality. Our air age has only just started, for in our traveling and transportation of goods by air, we are about to obsolete the wheel, just as the wheel and axle invention obsoleted the skid some 10,000 years ago.

In Russia, the aircraft builder reaches for success because he does not want to be sent to Siberia. In America, the aircraft designer used to burst with ambition, not only for fame, but for wealth rightfully earned. History shows that our greatest air progress was in those years when governmental restrictions were at a minimum and profitable free private enterprise at its maximum. Let us not wander from this too far, for we face a bitter rivalry.

The Use of Oceanography¹

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[With 2 plates]

THE DIRECTOR of the world's largest marine laboratory recently gave a vivid picture of the disadvantages under which marine scientists have to work. First, he pointed out, there is the great disparity between the size of the area to be studied and the number of scientists actually engaged on the study. Although the ocean covers an area well over twice that covered by land surfaces, the number of oceanographers is infinitesimal in comparison with the numbers of scientists engaged in the study of the land.

Then there is the baffling opacity of the ocean which defies attempts to penetrate it except by such means as lowering measuring and sampling apparatus on long wires or by sending down into the depths of the ocean a few intrepid scientists in one of the only two safe bathyscaphes now in existence. But the performance of such measuring and sampling apparatus can only be assessed indirectly, and the observers in the bathyscaphe cannot see anything that is more than a few feet away. Acoustic methods, which send sound waves into the sea and seek to distinguish between different kinds of echoes, show increasing promise, but they are a poor substitute for our eyes, and for the telescopes and aerial photography which can be used on land.

Another limitation arises from the fact that waves, currents, water movements, and sea conditions vary widely and as yet unpredictably with time and place, and can only be studied at the relatively few times and places accessible to research ships. Lastly, there is the disadvantage common to all large-scale problems in nature that little use can be made of controlled experiments—the forces involved are too large, and the time and space scales too great to be simulated in the laboratory. A well-known marine scientist has aptly summed up the position by asking how meteorologists would get on if they had to cover the whole

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of the Northern Hemisphere with half a dozen automobiles recording observations by flying kites on a moonless night.

However, it is not by enumerating the handicaps under which he has to work that the oceanographer can hope to rouse interest in, and win support for, marine science. Rather, he must point to the practical benefits that can be gained from the study of the ocean. He must show—if he can—that it will help us to get more food and raw materials from the sea and that this can be done without prejudice to future supplies; that it will improve the use of the sea for navigation or for such purposes as the disposal of waste products; that defenses against waves, storms, floods, and the silting of harbors will become more effective as we learn more about the sea. In other words, he has to show in what ways oceanography can be of practical use.

FOOD FROM THE SEA

The ocean covers over 70 percent of the earth's surface, and any part of it is, on an average, probably at least as fertile as an equivalent area of land. Naturally this fertility (and the same applies to the fertility of land surfaces) depends on a complex interaction of sunlight, nutrients, and other environmental conditions which may vary considerably from one region to another.

To reap the harvest of the ocean is at least as difficult a task as that of reaping the harvest of the land. The bulk of marine life is in the form of microscopic plants and animals, usually known as plankton, which are neither easy to gather nor agreeable to the human palate; we have therefore to rely almost entirely on their conversion into human food by fish and animals that have been nourished and fattened on them. In our ponds and streams we can practice some husbandry, but in the oceans we must still hunt for food and must face many of the problems that confront us on land. We are beginning to find that even in the most fertile areas stocks of profitable and edible fish are not inexhaustible, and that the profits of the chase depend on scientific knowledge, technical ingenuity, and capital expenditure. The increase in the activity and efficiency of commercial trawling and the consequent impoverishment of favorite fishing grounds have made it necessary to send ships farther afield and to intensify the drive for improved methods of detecting and catching fish. It is now possible for salmon to be taken in great numbers in the open ocean as well as in the rivers; tunny can be caught in midocean areas far away from their traditionally known haunts; and whalers now have recourse to the modern methods of underwater detection and aerial observation. It is significant that the methods developed by whalers for operations in the most distant oceans of the world are now being applied to fisheries in the North Atlantic; factory ships and transports are tending more and more to take the place of shore bases.

The need to help fishermen to get a good and steady return for their work without impoverishing the fishing grounds themselves has done more than anything to foster the study of the sea. This practical immediate aim has led to the specialization known as fisheries science; but it has also emphasized the need for precise study of all aspects of the ocean. This need has been greatest where there are large numbers of people who have long been dependent on food from the sea as well as from the land, and where long-established fisheries have become uneconomical, either through natural causes or as the result of intensive fishing. A paucity of fish unavoidably leads to friction, not only between fishermen but also between countries; and the best way of lessening such friction is to gain precise knowledge of the life histories, migrations, and feeding habits of fish in relation to their environment. Given sufficient understanding of the changes in numbers and distribution, a realistic basis for satisfactory agreement can be established.

But the task of gaining such knowledge is a very difficult one, because fish populations are affected by different conditions during spawning, hatching, and larval and adult stages, and we know very little about which conditions are favorable and which are not. Bad weather, low temperatures, and unfavorable currents may interfere with spawning and hatching; the success of the larval stages may depend on the presence of a particular current to take the larvae to favorable feeding grounds; and further development and growth of the adult may be determined by a whole range of physical and biological processes necessary to insure favorable living conditions and adequate food supplies. The International Council for the Exploration of the Sea, formed 60 years ago by the countries of northwestern Europe, has made good use of advances in knowledge and promoted many agreements on measures for regulating fisheries in the interests of all concerned. However, the number of disputes still occurring shows that much remains to be done in establishing facts and principles to prevent misinterpretations and misunderstandings.

A more pressing task, especially in countries with rapidly increasing populations, is the need to find and develop new fisheries. Sufficient light to cause photosynthesis is the first essential, but in temperate and lower latitudes, where there is plenty of sunshine, growth is often limited by shortage of nutrient salts, particularly phosphates and nitrates. Some guidance with respect to regions likely to be rich in nutrient salts can be gained by studying water movements. Warm surface water is generally separated from the colder deep water by a clearly defined transition layer in which the decrease in temperature causes sufficient increase in density to set up resistance to vertical mixing. There is thus a layer of relatively light water over one of greater density, and while the winter storms in cooler temperate latitudes are

sufficient to mix them, in lower latitudes the boundary layer and resistance to vertical mixing persist all the year round. In these latitudes the continual plant growth in the surface layer uses up the nutrients or reduces them to very low concentration. The underlying deep water is rich in nutrients because of the decay of sinking organic matter and lack of light, but the amounts of these nutrients which find their way to the impoverished surface layer are small because of the absence of mixing between the cold and warm waters. Anything which tends to encourage upward movement of cold water and to increase mixing thus leads to richer growth at the surface, and the boundary of any current or the site of any sharp change in speed and direction of current is a likely place to look for the physical processes which lead to greater mixing. Any boundary in the ocean, especially if the land lies to the left of the direction of the current in the Northern Hemisphere or to the right in the Southern Hemisphere (because of the earth's rotation), is thus likely to be richer in food than offshore water. But any change of depth, particularly at the edge of the continental shelf, may also cause upwelling; shoals and shallow waters around islands generally have a much richer flora and fauna than the deep water close at hand.

Far away from land, useful concentrations of fish have been found on boundaries of currents, such as that between the north equatorial current and the equatorial countercurrent. New ocean surveys have been planned in the light of such knowledge, and an understanding of the dynamics of water movements can be as good a guide in extending salmon and tunny fisheries into the deep ocean as a knowledge of shoals and currents has been to shallow-water fishing.

But while upwelling and mixing are over-all guides to regions of high productivity, an understanding of the actual living and shoaling habits of fish also require study. The areas richest in fish are not likely to be found where the water is coldest and contains most nutrients; it may be that water coming up from below has to remain some time at the surface before it can support a rich growth of plankton and fish. Most fish are thus generally found in the boundary regions between colder and warmer waters.

The distribution and shoaling habits of fish are also known to be affected by many other factors, such as winds, tides, currents, or perhaps an inlet of fresh water, and although there is often some local knowledge and experience available in this respect, there is too little systematized information on which further knowledge could be built. A better knowledge of water movements would also help to improve the operation of fishing gear and to develop new techniques, such as acoustic methods of finding, identifying, and counting fish, while a better knowledge of local movements of fish (and prawns) would in-

sure a more regular supply, and thus a more economical operation of freezing and canning plants.

RAW MATERIALS FROM THE SEA

China still takes at least 2 million tons of common salt from the sea every year, and India extracts some one and a half million tons; the world total is about 5 million tons per year. This, of course, is an infinitesimal fraction of the total amount of salt in the ocean. The world production of magnesium from the sea probably amounts to about 300,000 tons per annum, and that of bromine 100,000 tons. Many other chemical products are present in the sea, but they are so greatly diluted that no profitable methods for extracting them have yet been found. Potassium, for example, has been obtained from the ocean, but it is much more profitable to extract it from inland seas which are partly or completely dried up, such as the very saline Dead Sea or the marine deposits of Stassfurt (Germany), Alsace, and New Mexico.

The Chilean nitrate deposits, not to be confused with those of guano, are also believed to be of marine origin. Some iodine is still produced from seaweed, but most of the world's supply comes from the Chilean nitrate beds and from concentrated natural brines. The ultimate origin of petroleum seems to be the decomposition of organic material at the bottom of former, very fertile, ocean basins; if this is true, the immensity of petroleum reserves gives some idea of the scale on which the ocean can produce organic material.

The present problems encountered in extracting chemicals from the sea are the problems of chemical engineering concerned with the handling and the concentrating of large volumes of water; but a better understanding of geochemical processes, particularly of sedimentation and of the conditions under which mineral oils were formed, is likely to be a useful guide to the finding of further deposits.

POWER FROM THE SEA

Schemes to obtain power from the sea encounter the same kind of difficulty as processes for extracting chemicals: tides, waves, and currents contain large amounts of energy, but this energy is spread over such large areas or volumes of water that the installations needed to extract it would not be economical. Small tide mills have operated since early times, but large-scale projects have come to nothing; the British scheme for the Severn barrage never materialized, and the Passamaquoddy scheme in the Bay of Fundy (Canada), started in 1935, was soon abandoned.

Technical developments in the design of turbines have opened up new possibilities, and a large project (360,000 kw.) intended to pro-

duce 800 million kw.-hr. per annum has been started in France in the Rance estuary. This project is due to be completed in 1960 and, if successful, may lead to a much larger scheme embracing the Mont-Saint-Michel Bay and producing the equivalent of about half the electricity now consumed in France. Plans are also being discussed for another attempt in the Bay of Fundy. Such projects demand not only specialist knowledge of the tides and currents, but also a careful assessment of their effects on navigation, fisheries, and the configuration of coasts and beaches in the neighborhood.

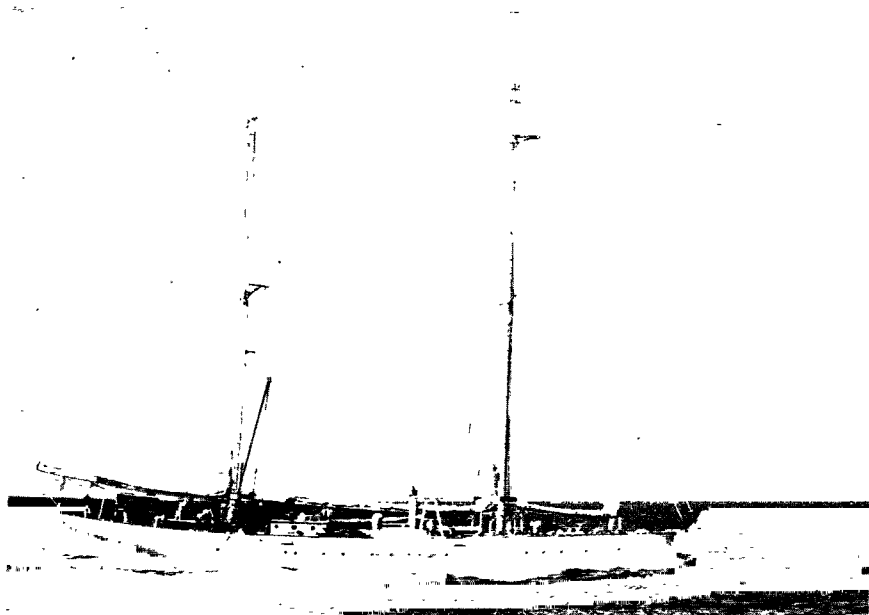
The power of waves is obvious to anyone who has seen the damage they can inflict; many a storm hits the coast with a force of a million horsepower per mile of coastline. But it would require an enormous engine to tap this force, and the operation would be more difficult than using the energy of tides. Small installations have been tried; a wave pump with an output of about one-half horsepower under favorable conditions worked for 10 years at Monaco; an installation in Newfoundland produced enough electricity to light a small house. These and similar schemes, combined with the use of new techniques and materials, seem reasonable enough to warrant a more thorough study of wave conditions.

Utilization of the relatively large and steady differences of temperature between surface and deep water in the tropical seas has engaged the attention of French engineers for many years, and an experimental plant at Abidjan, on the Ivory Coast, will soon be completed. This plant will produce large quantities of salt and fresh water as well as electricity.

NAVIGATION

Our greatest use of the sea is as a cheap highway for commerce; and although the ships of today are well able to face winds, waves, and currents, there is little doubt that time could be saved, and loss and damage avoided, if wave conditions and day-to-day changes in currents could be predicted reliably from weather charts and forecasts. The rewards will not be as spectacular as they were a hundred years ago when, by paying due attention to the new charts of prevailing winds and currents, a passage might be shortened by several weeks; but they will still be substantial. Ships' captains may not take kindly to following changing sailing directions from the shore; but the practice has been tried in a small way and has shown that ships can avoid storms and save time with less risk of damage.

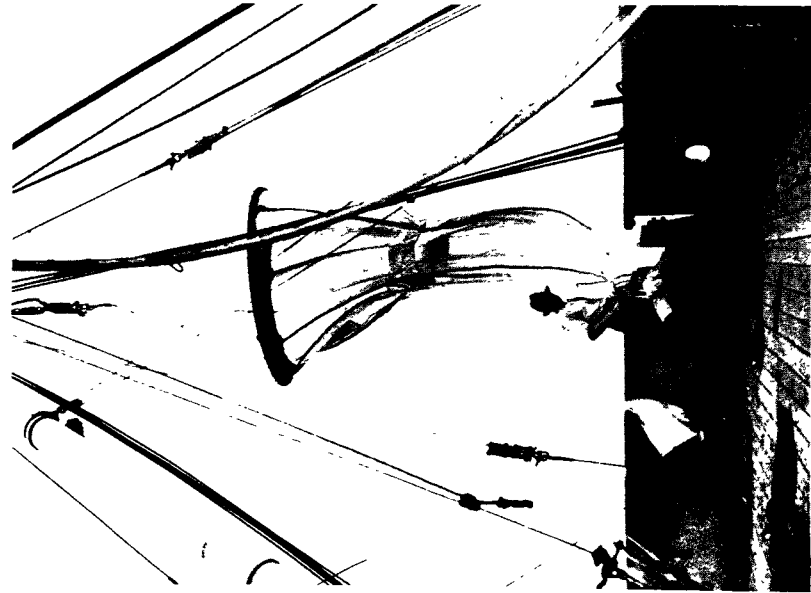
The study of ship movements in relation to waves has recently progressed to the stage where direct use can be made of reliable wave predictions. Much useful work has been done in this direction, and a number of authors have independently proposed formulae by which



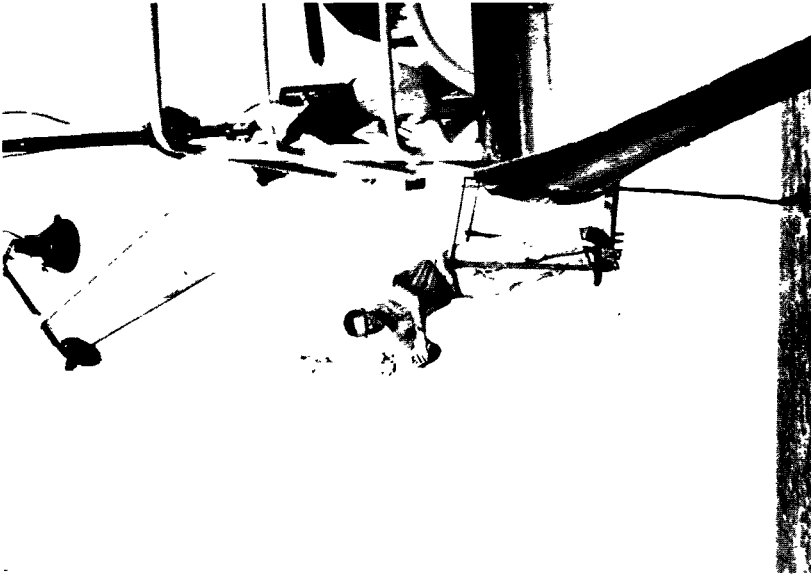
1. Research vessel *Atlantis*, Woods Hole Oceanographic Institution.



2. Royal research ship *Discovery II*, National Institute of Oceanography, U.K.



1. Working a 2-meter net from the stern of the *Discovery II*.



2. Working water-sampling bottles from the forecastle head of the *Discovery II*.

the main features of the wave pattern can be predicted from the speed, direction, and duration of the wind in the locality and in the adjoining ocean areas which contribute swell. These predictions are, however, of an empirical nature and have mainly local validity; much more work must be done before they can be of general validity and universal application. Such work would undoubtedly prove useful in the design of ships' hulls and in laying down operating speeds to suit different wave conditions, as well as in providing essential data for harbor design, coastal engineering, loading and unloading in exposed anchorages, passage over harbor bars, salvage operations, and oil drilling.

We already have excellent charts of the prevailing ocean currents, but these charts are careful to point out that day-to-day speeds and directions are variable, even in regions of strong current. The first observations in the Gulf Stream, made more than a hundred years ago, showed that the current was unsteady, and that it shifted its position so that the set varied in strength and direction, especially at the edges of the current. Since then, the averaging of many thousands of observations has tended to encourage geographers to represent the stream as broader and weaker than it really is. New observations between Cape Hatteras and Cape Cod, made with the help of modern radionavigational aids, show that the set in the fastest part of the current is often greater than is usually supposed; it reaches as much as 4 to 5 knots in a narrow region 10 to 15 miles wide near the landward side of the current. The observations show eddies varying from a few miles across to several hundred miles, and they also show that on occasion there can be strong countercurrents even near the usual axis of the current. Experiments by tanker companies operating along the U.S. Atlantic seaboard have shown that seeking out the strongest part of the current can save time. In regions of variable current a better understanding of the physical processes involved might improve safety measures.

Although the techniques of recording, analyzing, and predicting tides and tidal streams are already very effective, long series of observations cannot be made at every place for which predictions are required. To make the best use of a short or remote series of observations calls for a clear understanding of the effect of the tide-raising forces on seas of different size and shape, and of the factors which modify a tidal wave entering shallow water.

COASTAL AND HARBOR ENGINEERING

There are many potentially useful applications of tidal studies in connection with the changes in estuaries and channels brought about by silting and erosion. In fact, the interests of hydraulic engineers and

marine scientists are closely linked, and it has been said that the domain of hydraulics extends seaward as far as low-water mark, whereas that of oceanography extends landward as far as high-water mark. The bottom current is often different from that at the surface, so that silt and salt creep up the river estuary in spite of the greater outward flow of water at the surface. Better understanding of the mechanism by which both currents change speed and direction might well save some of the large sums spent on dredging.

Experience and sound engineering are essential to the design of coastal defenses, but they will not be able to be used to the best advantage until our basic knowledge of tides, waves, and beach currents reaches a more advanced stage. This lack of knowledge is usually offset by allowing a large margin of safety in engineering construction; but this often puts up costs so high as to make them prohibitive. Wave recorders, which allow us to gain a better understanding of various types of beach movement, are now available and are being installed in many places where constructional work is planned. It has been found that short, steep waves are most effective in eroding beaches and depositing the eroded material at greater depths to seaward of the beach; low, long swell returns the material to the beach, but if it comes at an angle to the beach it is very effective in moving material along the coast. Similar factors influence the growth and movements of bars, which can be a nuisance in the approaches to a harbor.

It is not likely that a simple and elegant solution can be found to all these problems. But most of the effort in coastal engineering aims at preventing beach material from being moved from some parts of the coast where it is needed to protect the land, to other parts where it is a hindrance to navigation; and it is only reasonable to assume that this work may be done with greater efficiency and economy when we have gained a better understanding of the physical processes involved. It may be added that a better knowledge of beach currents, especially the dangerous rip currents, would reduce the number of deaths from drowning.

Coasts and harbors are affected by surges and long waves which are of a type intermediate between ordinary waves and tides. One of the most common types is the surf beat—an oscillation associated with the more or less regular occurrence of groups of high and low swell approaching an ocean coast. The water level rises and falls several inches—and in exceptional conditions nearly a foot—over a period of 2 to 3 minutes. Many harbors have this surf beat, and the backward and forward oscillations can be sufficient to damage ships moored to a quay and to snap the mooring ropes if these are not kept continuously tight. The surf can also set up unpredictable movements near harbor

mouths and pierheads, which may add considerably to the difficulty of handling ships entering or leaving a harbor. Although the number of major ports seriously affected by this range action, as it is called, is small, there are some ports, such as Cape Town and Madras, where it is a serious problem. The recent International Navigational Congress (1957) urged that research be undertaken to establish the causes of the phenomenon, to predict disturbances likely to cause danger to shipping, to study the results of long-period waves, and to devise alleviating and remedial measures. Some evidence of increased silting due to this kind of oscillation was put forward at the congress.

There are other kinds of oscillation which may contribute to the range action; long-wave energy may be transmitted from distant storms, and natural oscillations are also present in gulfs, bays, channels, and larger areas of water such as the continental shelves. In small bodies of water shut off from the large oceans these oscillations are often more prominent than the tides; round the ocean coasts themselves their effect can be seen on tide-gage records, which every now and then take on a saw-tooth appearance as the regular rise and fall of the tide is disturbed by the local oscillations. We know very little about the causes of these oscillations, but it is presumed that local meteorological conditions have much to do with them. Experience shows that, in the case of long waves started by submarine earthquakes, the energy contained in a short burst of long waves coming from the deep ocean can be trapped in slower waves running along a continental margin, so that oscillations in a coastal region may persist for several days. There is also a possibility that disturbances may be prolonged by multiple reflections and refractions at the ocean boundaries, islands, and shoals.

It is not known whether long waves can be generated in deep water, but in shallow water (50 fathoms) it is not unusual for a long wave to travel at the same speed as a meteorological disturbance (60 knots), and in such conditions the wave, once started, is continually energized. This happens every now and then in the English Channel; a small change in wind or atmospheric pressure traveling at just the right speed causes a long wave, and an observer on the beach can see the water ebb and flow several feet in as many minutes. Coming quite unexpectedly, it can cause considerable confusion among small craft near the beach and some trouble to people on the beach.

The giant surges in the path of a hurricane, and when water is piled against a coast by a strong wind, are of much longer duration; they no longer appear as irregularities on a tide curve, but are as large as the tides themselves. Coasts near the path of typhoons and hurricanes and those with a wide, shallow shelf extending toward oncoming storms are the most vulnerable to flooding. They are the subject of

intensive study in many countries with a view to predicting their occurrence in time for all possible precautions to be taken, and to estimating the maximum height likely to be reached by the tidal waves so that appropriate defenses can be planned.

The study of all the effects meteorological conditions may have on water level is likely to be of considerable importance to navigation as well as to coastal engineering, because winds and variations in atmospheric pressure often significantly change the actual depth of water in a channel or over a bar. Even now it would pay most large harbor authorities to set up a small team to predict these meteorological disturbances of the tides.

MEAN SEA LEVEL

Industrial development of land near sea level—some of it reclaimed land—is now so great that changes in mean sea level, which may be quite significant over a period of 20 years or so, could have serious implications. The question is also important in geodetic leveling, where the results depend on information about changes in the volume of water in the oceans and about movements of water from one region to another, as well as on information about changes in the shape of the earth's crust. Mean sea level is obtained by reading the water level every hour from a tide-gage record and averaging the readings over a month or a year, with some allowance at the beginning and end of the readings to avoid falsifying the average by including part of an uncompleted cycle of the main semidiurnal or diurnal tide.

It has long been known that there are appreciable changes in mean sea level from month to month and from year to year, and that these changes are not merely local, but extend to separate and distant places. In most regions the monthly averages show an annual cycle, with the lowest mean level in spring and the highest in autumn. This is roughly what might be expected from seasonal changes in the density of the water and in the balance between precipitation and evaporation. The annual range of monthly mean level varies from a few centimeters at oceanic islands in the Tropics to as much as 165 cm. in the Bay of Bengal. More complete knowledge of these variations will help scientists to study changes of climate, exchanges of water between sea, air, and land, and the worldwide circulation of water. It also has some bearing on the problems of coastal engineering and geodetic leveling.

Study of the yearly averages shows that there are fluctuations from year to year as well as from season to season. On the Atlantic coast of the United States these fluctuations are generally less than 2 cm., but occasionally they may be as much as 5 cm. Between 1930 and 1949 there was an overall rise of 10 cm. of the water level in relation to the land. At Newlyn, near the southwest extremity of England,

the changes from year to year can be as much as 7.5 cm., and there has been an overall rise in level of 6 cm. over the past 40 years. These fluctuations, like the seasonal changes, probably depend on varying climatic conditions. The long-term rise is generally attributed to the melting of glaciers and polar icecaps, but in some regions subsidence or elevation of the land due to modifications in the earth's crust may be as important as changes in the level of the ocean. Although the southern part of England seems to be sinking in relation to the sea level, there is no change on the east coast of Scotland. Much has been written on the subject in the light of historical, archeological, and geographical evidence, and of tide records, but quantitative study is difficult without larger and more detailed measurements of both land and sea levels and without more knowledge of modifications in ice cover. Some of the changes—reaching as much as 15 cm. in 100 years in certain cases—are sufficiently large to warrant serious consideration in the planning and cost of seawalls.

EFFECT OF OCEANS ON CLIMATE

The atmosphere is very transparent to the sun's short-wave radiation, little of which is absorbed and that mainly by the water vapor and carbon dioxide in the air. Nearly half of the incoming radiation is reflected by the clouds and the surface of the sea and land; the rest is absorbed by the water and land surfaces. Storage by water is more efficient, first because water needs five times as much heat as does rock to raise its temperature by the same amount, and then because the overturning and mixing of water makes it store its heat deep down as well as at the surface. In the temperate regions, the effect of summer heating can often be detected down to 100 m. by the end of the season. Because of the greater specific heat of water and because of mixing, the day temperature rises less and the night temperature falls less at sea than on land. In the Sahara the night temperature can be 30° C. less than the day temperature, but in the same latitude over the ocean the difference is likely to be less than 2° C. Whence the contrast between maritime climate and continental climate.

Winds and currents play a large part in controlling climate. As far as we know, there is a rough balance of incoming and outgoing radiation over the world as a whole, but there are significant differences between one region and another. Winds and currents prevent the hot climates from getting hotter and the cold from getting colder by transporting large amounts of heat, mainly from lower to higher latitudes. The atmosphere has an active circulation, probably because it receives heat at the bottom from the land and sea, mainly by conduction and from water vapor, and is cooled at the top by radiation to space. But the oceans are heated and cooled at the same level, since the inward

and outward radiation and the transfer of heat to the atmosphere have their main effect at the surface, and this cannot produce very active convection. It has been estimated that the kinetic energy in the oceans is only about 2 percent of what it is in the atmosphere, and that most of this small fraction is derived from the atmosphere through the drag of the wind. But although the water movements are slow, they carry large amounts of heat and do much to determine the place at which most heat is fed to the atmosphere. In this way they influence cloudiness, the radiation balance, and winds. Winds and currents also influence the density layering in the ocean, and this in turn affects the response of the water to the wind and to differences in climate.

The interrelation of all these factors is too complex to be easily understood, but more and more emphasis is being placed on the need for comprehensive study. The lower atmosphere gets most of its heat from the sea, and a fuller understanding of the processes involved is needed to improve methods of forecasting warm, cold, wet, and dry periods for the benefit of food growers. Such knowledge may be useful in studies of weather as well as of climate, particularly in predicting hurricanes and typhoons, which all start over the ocean. It is also needed with respect to the oceans themselves—to enable fisheries scientists to predict how changes in wind and climate are likely to affect the water conditions in a fishing ground; and in the shorter run, to enable navigators to judge how particular wind conditions will affect a current.

The study of long-term trends in climate based on biological, geological, and archeological evidence is of interest to many branches of science—and has also some more immediate practical importance. The question of sea level is one example, since it is important to know whether the present rising trend is likely to continue. Another interesting example is the question of the average carbon dioxide content of the atmosphere; there is a possibility that this content is being increased by the growing expansion of industrial processes. The idea was previously dismissed on the grounds that the part played by carbon dioxide in absorbing the longwave radiation sent out by the earth was small compared with that of water vapor, and that in any case the carbon dioxide content of the atmosphere was controlled by the oceans, which have an almost infinite capacity for taking it into chemical combination as well as into solution. New estimates have revived the discussion, the idea being that by our present enormous consumption of coal and oil we are building a more effective greenhouse roof over our heads. This and other theories have been put forward to account for historical climatic changes. The idea must be given careful consideration, since a significant rise in the mean temperature would mean a reduction in ice cover of the arctic and antarctic

seas and lands which, in turn, would accelerate the rise of temperature by reducing the reflection of the sun's radiation and increasing the absorption. Such a train of events might provoke quite important changes in climate and sea level.

WASTE DISPOSAL

One of the greatest uses of the sea is as a receptacle for the disposal of waste. The opportunity thus offered has been so much abused near large towns or industrial centers that bathing has to be prohibited, and there is even some risk of disease. A satisfactory answer to the problem calls for a clearer understanding of the processes of diffusion and mixing, and of the manner in which they depend on waves, tides, and currents. The disposal of atomic waste has not so far been a difficult problem, since the amounts are small and are likely to decrease further as new uses are found for radioactive waste. But we should keep in mind the object lesson provided by previous experience in air and water pollution—where the threat has so long been ignored that it has now become a formidable menace. Short-term measures based on inadequate knowledge and taken under pressure from interested parties have not usually been satisfactory.

Although the spread of water from the River Thames across the North Sea seems to have a good rather than bad effect on fish populations, the general impression everywhere is that fisheries and weed beds are declining; and we are not certain that we are not gradually poisoning the oceans. More research will at least give a clearer picture of local problems and provide a foundation for a campaign to keep the sea clean similar to that launched against indiscriminate oil fuel disposal.

RESEARCH IN MARINE SCIENCE

The part which the sea has played in the cultural, economic, and political history of mankind has always been a great stimulus to the study of the oceans. But in contrast to the wealth of literature on the achievements of the early explorers and geographers, there is no well-balanced account of scientific investigations of the ocean; Krummel's "*Handbuch der Ozeanographie*"² is perhaps the best guide. Early scientists like Boyle and Newton took a great interest in the problems of the sea, as did later Lavoisier, Bernouilli, Laplace, Young, and others. Since the rapid growth of natural history in the 19th century, the main interest in the study of the ocean has centered on biological aspects, and today this interest is heightened by the fact that some of the fundamental problems in zoology can best be studied by using the simplest forms of life—which occur in the sea—and also that the

² The first volume published in 1907, the second in 1911.

results of such study are of practical importance to fisheries. But biologists themselves have always stressed the importance of studying the physical aspects of the ocean, i.e., water movements, since these must exert a great influence on the growth and distribution of the fauna.

Since oceanography clearly has a bearing on sea warfare and defense, it is not surprising that the two World Wars should have greatly stimulated the study of the physical aspects of marine science. The claims of defense, navigation, coastal protection, and harbor engineering, together with the realization that the latest research techniques can give valuable results when applied to the study of the ocean, have greatly contributed to the development of these aspects of marine science. The new physical studies are adding to the interest of biological studies, but they require rather expensive facilities. Most of the work is being done or fostered by Government-sponsored organizations which often cooperate when their interests coincide.

Useful work in the study of marine problems relating to fisheries has been done by the International Council for the Exploration of the Sea, mentioned earlier. Since its inception 60 years ago, other regional groups have been formed. There is also the work of the international scientific unions, and the International Union of Geodesy and Geophysics has an International Association of Physical Oceanography, which used to cover most aspects of marine research, but which now confines itself to the physical, chemical, and geological aspects only. The International Union of Biological Sciences, although it deals with marine studies, has no separate association for them.

Recently UNESCO initiated a marine science program. Its main object is to cultivate interest in oceanography, particularly in countries where it has not received sufficient attention. Pending the gradual development of a full-scale program, international and regional cooperation is being stimulated by means of symposia on regional problems, fellowships, visiting lectureships, and training courses. UNESCO is also endeavoring to get interested countries to build and operate a research ship, and is bringing together scientists to lay the foundations of regional cooperation in survey and research. Another task assumed by UNESCO has been that of acting as agent for the United Nations Organization in assembling information relating to problems common to many countries, such as the disposal of atomic waste and the regulation of the scientific investigation and exploitation of the continental shelves. The main task of cultivating interest in the subject and of promoting cooperation and a free exchange of ideas is one which UNESCO, with its area offices, is well equipped to do.

The International Council of Scientific Unions (ICSU), to which UNESCO makes a large annual grant, is promoting research at higher levels. It encourages and coordinates the activities of the scientific unions and furthers their mutual efforts in connection with subjects not adequately covered by existing arrangements. It has responded to the needs of marine science by setting up a Special Committee on Oceanic Research, which has put forward a well-considered plan for collaboration in studying the deep oceans. A start is likely to be made in the Indian Ocean, and a number of working groups representing all aspects of the subject are now being formed.

As can be seen from this short account, various interests of importance to many nations are involved in the study of the ocean. There must therefore be a good deal of international cooperation both in conducting oceanographic studies and in disseminating their results. It is only thus that we can reach that fuller understanding of the ocean which will help mankind to derive greater enjoyment from the blessings of the land.

Reprints of the various articles in this Report may be obtained, as long as the supply lasts, on request addressed to the Editorial and Publications Division, Smithsonian Institution, Washington 25, D.C.

Ambergris—Neptune's Treasure¹

By C. P. IDYLL

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[With 2 plates]

THERE is something ludicrous and yet pathetic in the contemplation of a fond mother storing a chunk of decaying malodorous flotsam from the seashore in her refrigerator in the vain hope that it will be the means of paying for her son's education. The hope that inspired her action, and which prompts scores of people every day to pick up and treasure the most repulsive pieces of dead flesh, jellyfish, yellowed wax, rubber, and hundreds of other objects tossed onto the beaches by the tides, is the expectation that they have found a piece of that romantic and improbable treasure from the sperm whale's intestine, ambergris.

The Marine Laboratory receives dozens of inquiring letters every week. Some are requests for the identification of queer sea creatures, others for advice on buying shrimp boats, still others want information on "everything about the ocean." The fattest file of all concerns ambergris. Everybody from tots to retired oldsters have heard of ambergris, and have gained greatly exaggerated ideas of its cash value. But the lure of easy riches, to be casually picked up on the beach, appeals to all of us. If there is added the romantic overtones of ambergris, the beachcomer is easily led to transmute anything he cannot identify into this treasure.

Interest in ambergris is by no means new. It is repeatedly mentioned in ancient oriental writings. Ideas of its origin are nearly as fantastic as the beliefs regarding its marvelous properties.

Very early the whale was recognized to be connected with the production of ambergris, but it was hard for observers to accept the leviathan as the primary source. Birds, trees, seals, crocodiles, and bees are among the creatures which were believed to be responsible, the whale simply swallowing their product.

Certain kinds of birds, especially those living on Madagascar, were supposed to produce dung which melted in the sun and ran into the

¹ Reprinted by permission from *Sea Frontiers*, vol. 4, No. 4, November 1958.

sea. Another tale involved the birds of the Maldive Islands, a group of coral atolls in the Indian Ocean. Barbosa says that the natives here believed that "there are certain great fowls which alight on the cliffs and rocks of the sea, and there drop this ambergris, where it is tanned and softened by the wind, the sun and the rain, and pieces both great and small are torn by storms and tempests and fall into the sea until they are found or washed up on the strands or swallowed by whales."

SPERM WHALE SOLE SOURCE

Just why the whale was regarded as incapable of manufacturing ambergris by himself seems unaccountable. And yet we know now that he is the sole source of this strange material. Precisely *how* it is formed is still a matter of conjecture, but it turns up in the intestine of the sperm whale, *Physeter catodon*, in the form of unattached lumps of varying size.

There is a good case to be made for the theory that squid, or cuttlefish, are connected with the production of ambergris, since the parrot-like beaks of these animals are usually found imbedded in the lumps. Squid beaks do not form a nucleus around which fecal material is impacted, as has been stated, since the beaks are found in any position in the mass—and are sometimes missing entirely.

Other early writers declared that ambergris was the hardened feces of the whale. Dr. Schwediawer in 1738, stated, for example, that "We may therefore define ambergris as the preternaturally hardened dung or feces of the sperm whale, mixed with some indigestible relics of its food."

This idea has been regarded by many recent writers with about the same amusement as the theories about Madagascar birds, yet Dr. Robert Clarke, the English whale expert, says, "I believe that Dr. Schwediawer was, quite simply, correct * * * Local increase in water absorption by the large intestine and the chemical transformation enacted by the resident intestinal bacteria, probably each play their part in the formation of ambergris from feces impacted around some matrix of indigestible material."

More observation is required on this point before any definitive statement about the exact manner of formation of ambergris can be made. The whale producing ambergris is not necessarily sick, as has been said, since perfectly normal whales have yielded lumps of this substance. Another theory, that only male whales produce ambergris, has also been shown to be false.

When ambergris is cast out by the whale it is usually in the form of stones or pebbles, rounded by the movement of the intestines. In the sea and on the shore it is usually broken up before it can be recog-

nized. Lumps of ambergris would easily be mistaken for rocks, unless their weight or their soft texture betrayed them.

Ambergris has been found over a large part of the world, but since the sperm whale is, generally speaking, a warm and temperate-water animal, most of the finds have been in the middle latitudes. The Bahamas, Brazil, Africa, Japan, Australia, the East Indies, Peru, Madagascar, and the Moluccas are the sources mentioned most frequently.

When ambergris emerges from the whale's intestine it is dark, almost black in color, of a sticky, bituminous nature. It stinks abominably, but as it spends more and more time in the water (floating on the surface owing to its low specific gravity), it gradually improves in odor and lightens in color. When found, the color is usually pale golden to dark brown, with the oldest lumps being chalky white. The latter are the most valuable.

From the fetid odor of the fresh material, ambergris changes progressively to a fishy smell, then to a sweetish musty odor reminiscent of the sea. Many curious adjectives have been applied to the odor of ambergris: "earthy, reminiscent of brazil nuts," "musky," "a light sea odor," "an indole odor of the fecal type," "a moist incense odor."

STRANGE AND ROMANTIC USES

The uses to which ambergris has been put are as strange and romantic as its real and imaginary origins. One modern use, at least in the Western world, is in the manufacture of perfume, but this was not always so. Formerly, it found its way into food, drink, medicines, and tobacco. Its widest use was as an aphrodisiac. Just how this dingy-looking material came to be credited with the power of heightening erotic desire is a mystery, and the man who first summoned enough courage to eat ambergris deserves to be remembered with that unknown hero who ate the first raw oyster. Whoever this worthy was, he soon had plenty of followers.

In the middle of the 17th century Sir John Chardin wrote that the Persians used musk and ambergris in abundance in several sorts of their sweetmeats and confections—the one (musk) only to fortify or strengthen, the other (ambergris) to stir up love, and which the people of condition seldom failed to eat both before and after meals. It was especially valued by the Chinese, who as early as the 13th century, used to send as far as the east coast of Africa to get it, together with gold and ivory. They called it "lung yen," or dragon's saliva.

Ambergris was credited in India with power to assist women suffering from complications of childbirth, while the Chinese believed it assisted in the growth of marrow and semen. Several oriental peoples believed that it extended the span of life.

Other supposed medical virtues of ambergris are as varied as they are fascinating: A remedy for hydrophobia, epilepsy, typhoid fever, nervous diseases, gravel, and for stoppage of the bowels. "It was formerly regarded as a cordial and antispasmodic like musk * * * a diuretic * * * gets rid of body parasites of tubercular patients and dispels ghosts." It was "able to dispel evil spirits and was used for devil possession and for asthma."

Nor is this the end of the medical wonders attributed to ambergris. It was further said that it "eases the headache, takes away defluxions from the eyes, comforts old and aged people, prevents apoplexy and epilepsy, strengthens all parts of the body and causes fruitfulness." Leonard Stoller quotes another ancient writer to the effect that the Cantonese made ambergris into pills which were everlasting and could be chewed for years without diminishing in size.

USE AS A FIXATIVE

Ambergris can be used only in the finest and most expensive perfumes. Its action is as a fixative. It adds almost nothing to the odor of the perfume itself but has remarkable powers of maintaining the scent of the odorous constituents of the perfume. Musk in a perfume will give it the maximum diffusive power, while ambergris will give it the longest duration of evaporation. While perfumes prepared without ambergris last for days, those made with it will last for as many months, according to one expert. Ambergris imparts a subtle velvetiness unobtainable otherwise.

The starting material for the formation of ambergris is ambrein, which is present in some kinds of squid, eaten by sperm whales. Ambrein is a white solid, forming slender needlelike crystals which become highly electrified upon rubbing. In the presence of vanadium or copper and upon exposure to sunlight, air, and seawater, it is transmuted into ambergris.

SYNTHETIC AMBERGRIS

Swiss and German chemists, after 30 years of research, have succeeded in creating ambrein artificially, and it is on the market under the trade names of "Ambropur" and "Grisambrol." The two principal intermediate constituents are gamma-dihydroionone and ambreinolide. The former is responsible for the faint characteristic odor of ambergris and the latter for its fixative qualities.

In 1956 the new synthetics sold for about one-ninth the price of good-quality natural ambergris, and their price makes them available for use in cheaper perfumes. In addition, at least one firm is seriously investigating the aphrodisiac qualities of the synthesized material for its possible use in animal husbandry. This serves to prove how hard

it is to kill old myths—or else to prove that the ancients were not as stupid as we sometimes like to believe!

With all its desirable characteristics, supposed and real, it is little wonder that ambergris has demanded a high price, especially in former times when the uses were more varied than they are today. A thousand years ago it was a familiar item of commerce in Africa and was classed with black slaves and gold as one of the important products of Maghreb, the ancient Arabic designation for the northern part of the Dark Continent. Ambergris was once literally worth its weight in gold. The East India Co. normally paid between 50s. and 70s. per ounce—and in the valuable shillings of the 17th century!

HOW MUCH TODAY?

In 1942 a perfumer is quoted as saying that ambergris was worth \$20 an ounce, but if this were in fact true then, it certainly is not today. It is, of course, impossible to state "the" price on the present market, since the quality of ambergris varies so greatly. In answer to an inquiry in 1958, four of the leading perfume manufacturers quoted the following ranges of prices per ounce: \$2–\$6, \$3–\$4, \$4–\$8, and \$8–\$9.

Most of the ambergris of commerce comes from the whaling industry and, as our correspondents put it, "individuals connected with shipping." Some of the notable finds have occurred in recent years. Dr. Robert Clarke, the British scientist mentioned earlier, found a piece weighing 926 pounds in 1953. This enormous chunk of ambergris, 5 feet 5 inches long and 30 inches around in its greatest diameter, came from a 49-foot male sperm whale caught in the Antarctic. Dr. Clarke says this is the largest piece actually examined and authenticated. He lists four larger weights of ambergris mentioned in the literature but regards three of them as probably comprising more than one piece. The fourth, weighing 982 pounds and reported by the Dutch East India Company in 1880, may be the largest single piece ever recorded.

Smaller, but still notable, finds of ambergris are numerous in the written accounts: A piece weighing 182 pounds purchased from the East India Co. by the King of Thydore; a 280-pound piece from New Zealand; a 350-pound piece taken by a Norwegian whaler; 750 pounds from a whale in 1859, by a Nantucket whaler. A 53-pound piece found near Scotland was sold in London for \$42,750. As late as 1956, a piece weighing 151 pounds 8 ounces was sold in this country for \$20,000.

So, not only is ambergris no longer worth its weight in gold, but to further explode the myth that it provides riches to be picked up on the beaches of the world, the chance of finding it there is extremely slim.

Each of four perfume firms answering a query stated that it was rare for an individual to find genuine ambergris. Said one, "In all my 40 years' experience as a perfume chemist I have yet to meet an individual who has found real ambergris."

Actually, people who have sent material to the Marine Laboratory in the past 16 years have a little better record than that: Two out of several hundred actually found the real thing. Both of these finds were in the Bahamas; one was a tiny piece weighing less than an ounce, while the other was much more worthwhile. This latter weighed about 200 pounds, consisting of one chunk of about 125 pounds and numerous smaller pieces. It was found by Samuel Nixon, of Inagua, Bahamas, early in 1955 and was sold to a Nassau firm for £500. But for each of these two finds—one insignificant and one valuable—there have been hundreds of blanks drawn by the beachcomers.

HOW TO TEST

The Laboratory has issued a bulletin describing tests which can be applied in identifying ambergris. Positive identification is the job of an expert, and even the best of these can sometimes be fooled. E. W. Bovill, who had intimate association with ambergris for many years as a dealer in the substance, relates how he and A. C. Stirling, another world authority on ambergris, paid a considerable sum for what they thought was a small piece of the valuable white variety—only to find on breaking it that it had a wick, and was a piece of wax candle, much weathered by the sea!

Despite the difficulties of foolproof identification, even a layman, by applying the tests below, can eliminate at least 95 percent of what he might hopefully believe to be ambergris. Says the bulletin in part:

True ambergris * * * usually has the consistency of wax or pitch, but may be almost brittle * * * Ambergris will not dissolve in water, but floats even in fresh water, having a specific gravity between 0.78 and 0.98. It melts in hot (145° to 150° F.) water well below the boiling point.

The simple hot wire or needle test for true ambergris requires no special apparatus. Heat a piece of wire or a needle in a gas or candle flame for about 15 seconds and then press it into the sample to a depth of one-eighth of an inch. If it is genuine ambergris, a dark brown to black, opaque, resinous liquid will form around the wire and appear to boil. (If the sample is wax, the liquid will be clear). Then withdraw the wire and, before the melted material on the wire cools, touch it with your finger. True ambergris will leave tacky, pitch-like "strings" sticking to the skin. (Most waxy substances so treated either cleanly coat the fingertip or merely take its impression.) When cold, the string of melted ambergris is shiny and resembles dark brown or black enamel.

When the wire, which retains portions of the melted material, is again placed in the flame, true ambergris will soon emit a white fume having the same characteristic odor as the solid, and then burn with a luminous flame. (Waxes do not emit fumes until almost ready to ignite, and the fume has a typical "hot wax" or acrid odor.) Note the odor of the smoke when the flame is extinguished. It should have the odor of burning rubber.



1. Ambergris in the raw does not look very romantic, but it is used in the finest perfumes as a fixative.



2. Most of the ambergris of commerce comes from the whaling industry, through the use of harpoon guns, like the one shown above.



1. A simple test for ambergris is to heat a piece of wire for about 15 seconds and press it into the sample. If it is genuine ambergris, a dark resinous liquid will form around the wire and appear to boil.



2. This is one of the largest pieces of ambergris ever found, being over a yard in diameter.



3. The sperm whale is the sole source of ambergris. Considering its huge size, it has a small mouth.

One quick test is to dissolve a little piece in a small quantity of hot wood alcohol (methyl alcohol), then allow it to cool. True ambergris will crystallize as the alcohol cools.

A glance eliminates the great majority of materials sent to our laboratory. One of the most recent samples was a small bottle of what at first appeared to be a watery liquid. On closer look a small, very dead jellyfish could be seen. More commonly the samples consist of materials a good deal closer to the actual form of ambergris. Candle wax and pieces of rubber are common; carnauba wax (a yellowish product of South American palms, used in polishes) is frequently encountered.

So the usual phrase in our letters of reply to hopeful people, like the lady mentioned in the opening paragraph, is "We are sorry to tell you that your material is not ambergris."

Still, this strange, amorphous substance does exist, and who knows—someday you may beat the odds and actually find a piece of that marvelous product of whale's bowels and send it on the first leg of its journey to a fashionable lady's perfume!

Reprints of the various articles in this Report may be obtained, as long as the supply lasts, on request addressed to the Editorial and Publications Division, Smithsonian Institution, Washington 25, D.C.

The Rhythmic Nature of Animals and Plants¹

By FRANK A. BROWN, JR.

*Morrison Professor of the Biological Sciences
Northwestern University*

*The Year's Awakening**

"How do you know that the pilgrim track
Along the belting zodiac
Swept by the sun in his seeming rounds
Is traced by now to the Fishes' bounds
And into the Ram, when weeks of cloud
Have wrapt the sky in a clammy shroud,
And never as yet a tint of spring
Has shown in the Earth's apparelling ;
O vespering bird, how do you know,
How do you know ?

How do you know, deep underground,
Hid in your bed from sight and sound,
Without a turn in temperature,
With weather life can scare endure.
That light has won a fraction's strength,
And day put on some moment's length,
Whereof in merest rote will come,
Weeks hence, mild airs that do not numb,
O crocus root, how do you know,
How do you know ?"

THOMAS HARDY

LIVING THINGS inhabit a world replete with rhythms. Nearly every aspect of the physical environment exhibits rhythmic changes. From the submicroscopic atoms, comprising systems of negatively charged

¹ Research program on rhythmicity was aided by a contract between the Office of Naval Research, Department of the Navy, and Northwestern University. This article reprinted by permission from Northwestern University Tri-Quarterly, vol. 1, No. 1, fall 1958.

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electrons sweeping in orbits about positively charged nuclei, to our solar system of planets, including the earth, revolving in their orbits about the sun, the observable, relative stability of nature is dependent upon such rhythmic or periodic changes.

The external physical environment of living organisms displays well-known rhythmic changes. The rotation of the earth on its axis relative to the sun provides the daily 24-hour period with its extensive changes in light, temperature, and humidity. The rotation of the earth relative to the moon provides our lunar-day periods of 24 hours and 50 minutes. The lunar-day fluctuations in light and temperature are, however, feeble compared with those of the solar day. These two daily rhythms cooperate with the orbiting of the moon about the earth to provide monthly cycles of $29\frac{1}{2}$ days, the period separating two consecutive times of synchronization of solar and lunar noons. Both sun and moon are responsible for producing tides in the oceans and atmosphere of the earth. The sun is the more influential of the two in the case of the atmospheric tides, and the moon the more influential for the oceanic ones. The solar and lunar tides of the atmosphere are associated with more subtle physical changes such as barometric pressure, cosmic radiation, gravity, magnetic field, and atmospheric electrical potential. The earth also revolves about the sun with its axis oriented in such a manner as to yield the annual rhythm of the seasons. Finally, the sun itself rotates on its own axis with an average 27-day period, and since the sun's surface is not uniform, an additional rhythmic change with a 27-day frequency is imposed upon the surface of the earth.

The physical environment of living things is truly a composite of rhythms.

It might be presumed, therefore, that living things, as complex, delicately balanced, physico-chemical entities lying at a level between atom and solar system, persist as stable beings only through some kinds of comparable rhythmic fluctuations about mean values. In fact we do not need to go beyond our own bodies to be impressed with the existence of such rhythms. Man has daily cycles of many processes such as wakefulness, blood-sugar concentration, blood-cell count, and body temperature. For example, our body temperature tends to be lowest, other factors equal, about 5 to 6 in the morning and highest about 5 to 6 in the evening. Another familiar cycle is the reproductive, which follows the lunar month.

Very widespread among the animal and plant kingdoms are daily, lunar-tidal, lunar monthly, and annual cycles of innumerable activities; and where biologists have sought them, 27-day cycles have been observed as well. It can be said without equivocation that rhythmicity is the rule in living things. These rhythms are often highly useful

ones. Like the boxer in the ring, the organism in its rhythmic environment is able to yield before the periodic blows and to advance after them. In its rhythmic physical environment, the rhythmic organism is therefore adapted, figuratively speaking, to make hay while the sun shines, in preparation for the dark, cold nights.

The spectacular, complex character of the rhythmic nature of living things first impressed me about 25 years ago as a young visiting investigator at the Bermuda Biological Station. One of the fascinating pastimes was to sit on the laboratory jetty in the evening after dark with the water beneath illuminated by an electric lamp. Myriads of living things, attracted by the light, would swim into the area. All the creatures were easily identified because biologists had thoroughly studied the flora and fauna of the Island and published extensively upon them. But one night about 10 o'clock, the water suddenly became charged with ghostly, transparent, strange shrimp. We captured some but a careful search revealed that these had never before been seen at Bermuda. They were sent to the British Museum, where it was learned that only one male specimen had ever before been caught—and that one in the Indian Ocean about 50 years earlier. It turned out that these shrimp are abundant at Bermuda, but swarm in hordes only for an hour or two just before midnight near the time of new moon. A 2-year study by Wheeler of the fluctuation in abundance of these shrimp at different times of the lunar month showed one swarming peak to occur two days after new moon, and a second larger one 3 to 4 days before new moon. No one knows yet where they conceal themselves the rest of the time.

Such a precise lunar rhythm of swarming to assure the bringing together of large numbers of males and females for breeding and maintenance of the species is commonplace. Another and better-known example of lunar swarming for breeding purposes is that of the palolo worm of the southwest Pacific. At a predictable time of day at the times of the October and November third quarter of the moon, elongated posterior ends of these worms, filled with reproductive cells, break off and swarm from the burrows in the coral rock in such numbers that they are readily scooped out of the sea. The predictable occurrence of these delectable, edible worms determines the time of feast days for certain South Sea islanders.

Coming closer to home, newspapers of coastal areas of California indicate for their readers the exact hour when they can go to their sandy beaches and expect to catch a highly prized, small edible fish, the grunion, as they swarm in from the open sea and throw themselves onto the beaches. This they do from April through June at that exact time of the month when the sun and moon are cooperating to produce the highest high tide of the month, and a few minutes after

the exact moment of high tide. These fish normally reproduce by depositing eggs and sperm in pits they dig in the wet sand just out of reach of most high tides. Here the young fish develop and are ready to take off to sea at the time of the next monthly high high tide.

We do not have to select illustrations from animals alone, since even seaweeds are known which have lunar-monthly reproductive cycles. These are critical for the species; they synchronize the production of eggs and the sperm which must fertilize them.

Examples of solar-day and annual rhythms of living things in nature are legion. Every one of us can think of organisms that are habitually nocturnal, diurnal, or crepuscular in their daily time of activity, and axiomatic are our spring and fall waxing and waning of the activities of innumerable plants and animals. And along the shores of our oceans where the tides monotonously rise and fall with lunar-tidal frequency, 50 minutes later each day, are corresponding rhythms of activity of the organisms that live there: some, like oysters, which filter their food from the sea water are active only when covered by water at flood tide; others, like the foraging fiddler crabs, scour the beaches for food exposed at ebb tide.

Animals, furthermore, do not have to dwell on the seashore to display a lunar-tidal rhythm. There is the often-quoted observation of the reef heron, which lives on the mainland of Australia up to 30 miles away from its feeding ground on the reef where it preys upon animals exposed at low tide. Each day this bird departs from its roost on its trip to the reefs just at the proper time to take advantage of the low tide—50 minutes later each day. This phenomenal timing ability led one writer to remark, "Here is a sixth sense if ever there was one."

Another kind of example of a daily rhythm is seen in birds such as the starlings, which, in their north-south migrations in Europe, have been demonstrated to utilize the sun as a compass through holding their bodies at a fixed angle relative to it. But the sun during a day-long flight gradually moves across the sky from east to west. Kramer and Matthews both reported that the birds continuously corrected for the changing position of the sun in order to maintain a fixed, straight, compass course. Kramer spectacularly demonstrated this by placing birds in a domed enclosure possessing an artificial sun fixed in one position. Under these conditions, the direction of orientation of the birds relative to the artificial sun gradually changed during the day, exactly as one would have predicted on the basis of the rotation of the earth. Some beach fleas which migrate up and down the beaches have similarly been proven by Pardi and Papi to use both sun and moon as their compass, correcting with equal facility and accuracy to the normal movements of each.

A final kind of illustration to familiarize one with roles of rhythms in organisms comes from studies of the time sense of organisms. Beling found that if honey bees are fed sugar water at a particular place and time of day for a few days, they will continue to come back to the same place at the same time of day. They even continue to come back for several days when food is no longer provided. This kind of time training can be accomplished only on a 24-hour periodic basis. One cannot teach them, say, to feed at regular 19-hour intervals. This learning process, therefore, in some manner involves their 24-hour rhythm.

The foregoing selected examples of biological rhythms suffice to illustrate their widespread distribution and a few of the innumerable ways they may be put to use by living things. Now let us pass on to some studies of the mechanisms of the rhythmicities.

The most obvious explanation of the daily rhythms that occurs to one is that the organisms are simply responding to the daily cycles in light, temperature, or humidity, and that the lunar-tidal rhythms of shore dwellers are simply direct responses to the rhythmic ebbing and flooding of the tides. This hypothesis was easily testable, and was, in fact, first tested about 200 years ago. Many plants were known to show a sleep rhythm involving the drooping of the leaves by night and their elevation by day. Zinn, in 1759, found that plants would still show the sleep rhythm when no light or temperature changes occurred. This observation was confirmed and studied extensively early in this century using the bean seedling, and such work is now continuing actively in the laboratory of Professor Bünning and his associates at the University of Tübingen, in Germany. A general method of recording automatically the leaf movements on a slowly rotating drum is illustrated in figure 1.

The persistence of the daily rhythmic processes in living things in conditions constant with respect to all factors generally conceded to influence the organisms has now been demonstrated by numerous investigators for living things representing the gamut of the animal and plant kingdoms, and ranging from single-celled microorganisms to the most complex of multicellular larger ones.

Fiddler crabs in nature start to blacken their skin about sunrise in the morning to hide themselves better from their predators, and to screen their delicate internal organs from the intense sunlight of the unshaded beaches, and about sunset they rapidly blanch until their bodies are pale silvery gray. This is more evident for their legs than for their bodies, since the shell covering the legs is quite transparent. Even crabs captured and maintained in constant conditions in a photographic darkroom continue for weeks or months to darken

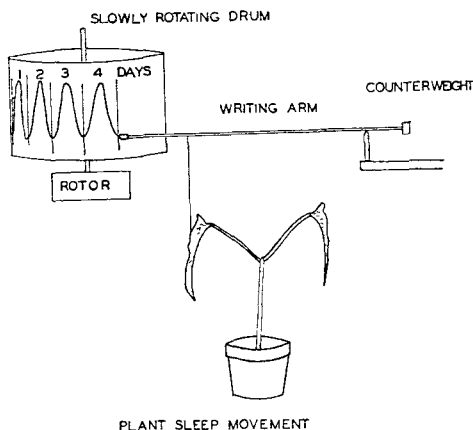


FIGURE 1.—Apparatus for automatically recording sleep movements in the bean seedling.

and lighten each day in synchrony with their relatives still free in their natural day-night environment.

Another, and very interesting, property of these rhythms persisting in darkness is that they may be easily reset so that events in the rhythm occur at times of day other than the normal ones. This may be illustrated by the crab color-change rhythm. If this is proceeding normally in constant darkness and temperature (the top line of fig. 2), showing maximum darkening at noon and blanching at midnight, and we simply, for two or three days, leave lights on in the darkroom from midnight to noon, we find at the end of this treatment that the crabs still possess an accurate daily rhythm of color change which persists in darkness indefinitely, but now (as in the second line in fig. 2) it has been shifted so that the color changes occur at an earlier time of day, by 6 hours. They now darken most at 6 a.m. and blanch most about 6 p.m. In a comparable manner we may set the actual time of the color changes in the 24-hour rhythm to any time of day, and there it will remain until reset. The third line of figure 2 shows crabs which were subjected to three lighted nights and darkened days; the cycles are inverted. An alternative way to reset the cycles is through giving the crabs, while in constant darkness, experimental cycles of abrupt temperature changes. High temperatures act like light, lower temperatures like darkness. A third way to reset them is simply to place crabs with normal cycles in constant darkness on ice cubes for the number of hours one wishes to set back the cycles. When taken off the ice the crabs' color-change rhythm picks up right where it left off when they were first iced (fourth line of fig. 2) and hence the phases are slow by a time correlated with the period of chilling. It is as if self-starting 24-hour clocks were stopped near freezing temperatures.

Fiddler crabs in nature romp most actively on the beaches seeking food about the time of low tide. When these crabs are brought into the laboratory and kept in vessels in a photographic darkroom, then, like those still left on the beaches, they continue to show their greatest running activity at the times when it is ebb tide on their native beaches, and remain relatively quiet at the time of flood tide. The time of maximum running occurs, therefore, later each day at the expected lunar-tidal rate. If in the same darkroom at the same time we place



IN CONTINUOUS DARKNESS

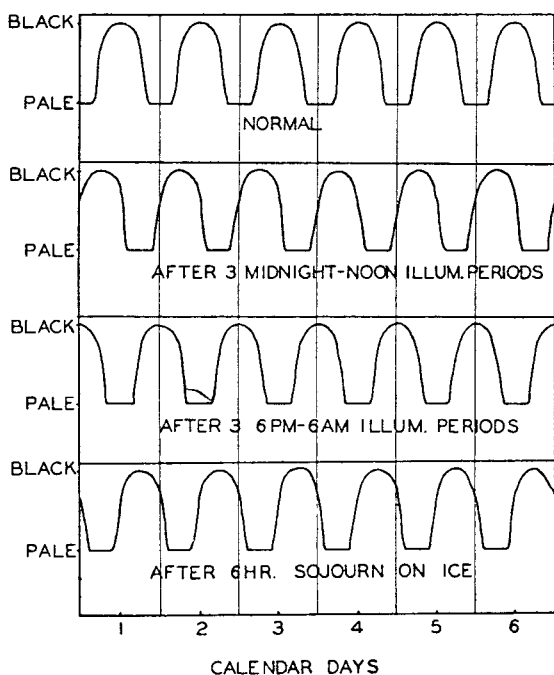


FIGURE 2.—Daily rhythm of color change in fiddler crabs and some of its experimentally altered phase relationships.

two groups of crabs, taken from two different beaches on which the time of low tide was different by several hours, each group of crabs may continue to signal the time of low tide on its own beach. So, simultaneously in the same crabs deprived of all ordinary cues relative to time of day or tide, there persists, on the one hand, a solar-day rhythm of color change and, on the other, a lunar-tidal cycle of spontaneous activity.

Studies comparable to these, using numerous other kinds of animals and plants, have demonstrated quite clearly that, like the daily, the

lunar-tidal rhythms do not depend upon any known kind of external cues for the measurement of the lunar-period lengths.

The 24-hour rhythm seems very deeply ingrained in organisms. We showed a number of years ago that even if rhythms seemed completely halted, as in the instance of color change in crabs held in very bright light for 10 or 12 days, a regular rhythm would reappear at once when the crabs were replaced in darkness.

It has been satisfactorily demonstrated that an organism need never have experienced a single normal daily cycle in its life, and yet be capable of exhibiting a precise daily cycle. Hence the cycle cannot be contemplated in any sense as a period of day length remembered by the organism. It was shown long ago that beans grown in constant darkness show no rhythmic sleep movements, but a single brief light shock will start off a persisting 24-hour rhythm, the time of day of awakening onset, a function of time of the light shock. Fruit flies normally, as they are about to complete their development, emerge from their pupal cases as fully active flies about daybreak, Dr. Brett, in my laboratory, showed, however, that if a batch of eggs is laid and development is caused to occur wholly in darkness, flies emerge at all hours of the day. But if during the development of the fly larvae in darkness, a single flash of light, as brief as one minute, is given them, then the flies will emerge from their pupal cases, up to days later, after completing their development and pupating, at the same time of day as the time the light flash was given. The light flash could not have imparted information as to the length of a 24-hour period to render this possible. The flies behaved quite as if they all had operating 24-hour rhythms of emergence but had had nothing by which to set them to the usual time of day. The brief light flash seemed to be treated by all the developing flies as the onset of a dawn, and with this, all the rhythms were synchronized. Flies normally emerge at dawn.

A deep-seated daily rhythmicity of still unknown significance was discovered recently by Professor Bünning and his associates. This is a rhythm of swelling of the nucleus of cells of a number of plants. In the daily changes the nucleus is largest about 6 in the morning and smallest at noon. I have spoken of this rhythm as deep seated because the cell with its contained nucleus constitutes the fundamental unit of organization of all living things, whether plant or animal.

It is a commonly experienced phenomenon when we have made long east to west or west to east airplane trips that we have moved to a new longitude without having reset our own internal 24-hour rhythms. If, for example, we had lived for a time in New England and were accustomed to awakening at 7 in the morning, and now flew to take up residence in California, we would find ourselves, in California, awakening and disconcertingly being quite wide awake, about

4 a.m. Pacific standard time. In doing this we would still be following our 24-hour rhythm; this is, of course, 7 a.m., eastern standard time. But after a few days of experiencing the California social and day-night rhythms, we would have reset our rhythm to Pacific standard time and would have the same kind of experience, but now in reverse, were we to fly back to New England.

The foregoing is an example of a fundamental property of rhythms of living things which has given biologists more information. My associates and I performed an objective experiment of this nature with fiddler crabs a few years ago. Crabs, which were changing color in a darkroom in our laboratory on Cape Cod, Mass., at the usual times, dawn and dusk, were divided into two equal-sized batches and sealed in lightproof cartons. One batch was carried by airplane to be opened in an experimental darkroom at the University of California the next day. Synchronously, by prearrangement, the other group was opened in a darkroom on Cape Cod. The rhythms of color change in the two lots of crabs on the two sides of the continent was studied. The times of darkening and lightening for the two batches were carefully compared. Both were on eastern standard time. The crabs that had traveled to California kept their rhythm on eastern standard time, both during the trip and during the 6 days in California that they could be studied. The average time difference for the 6-day period was only 12 minutes; this was within the error of our measurements. The crabs showed no tendency to shift their rhythms to accord with the dawn and dusk of California.

From this last experiment it was possible to draw certain conclusions. (1) Since, during the day of their westward trip, the crabs had been subjected to an artificial day of 27 hours and 20 minutes with respect to any and every "local time" factor that possessed its 24-hour period as a consequence of the rotation of the earth relative to the sun, the crabs clearly could measure one 24-hour period without any kind of clue, even a subtle one, of this nature. (2) Once in California where rhythms of many physical environmental factors were once again 24-hour ones, the crabs could retain an accurate 24-hour rhythm in a new time relationship relative to the external ones. (3) To reset their rhythms to Pacific time, the crabs needed exposure to one or more natural California light cycles.

The year following this study on the crabs, a completely comparable experiment was performed by Renner, using the time sense of honey bees. Completely duplicate bee-training rooms were built and furnished in Paris and in New York. Bees were trained to come to a particular spot in the Paris room for food at a particular time of day. Once trained, the bees were sealed in a container and flown to the room in New York. The bees, now in New York, came to the feeding spot

at the proper time for Paris. They were retrained in New York and flown back to Paris. In Paris they came to feed at the proper time for New York. This confirmed completely our crab experiments.

These experiments, however, did not prove that a rhythm of some subtle external factor was not essential to the organismic 24-hour rhythm since there are certain important 24-hour rhythms in the environment that are on universal time. By universal time is meant that the rhythm affects all regions of the earth's surface in the same ways at the same instants. Such a factor is the daily fluctuation in the 300,000-volt potential difference which exists between the surface of the earth and one of the outer shells of our atmosphere, the ionosphere. By one of these universal-time cycles the 24-hour period could conceivably be imparted to the animals even while they are traveling. On the other hand, the living rhythmic system might be completely independent of all external cycles.

We have seen thus far that the daily rhythms of living things in constant darkness, like the clocks in our homes, can measure accurately 24-hour periods whether they are set at the normally correct time of day, or have been reset to register an incorrect time. As the mathematician or physicist would describe this, the rhythms in the living things need not have locked phase relations with any external physical rhythms. On the contrary, there is a freely labile relationship. This adjustability of the biological cycles is a very useful characteristic. Absence of this property would make the rhythms comparable to alarm clocks in which the time of day or the ringing of the alarm could not be altered.

This brings us to another of the interesting properties of the rhythms of living things, namely, that many are known regularly to gain or lose a few minutes every day. Some are even known which regularly gain or lose two or three hours a day. Such a one as the last is the spontaneous activity of the field mouse, or the white rat. Both of these animals, when kept in constant darkness, may exhibit an accurate 24-hour cycle of running with about 12-hour periods of activity alternating with about 12-hour periods of rest, but when kept in an unchanging low illumination have their daily cycles of running longer than 24 hours. In the rat we found them to be quite regular and $25\frac{1}{4}$ hours in length. In figure 3, starting at the top, the blackened areas indicate the times of day of running during 70 days in constant dim light. To begin with, the rat, like any well-adjusted rat, ran only during the early morning and the evening hours. Since the rat started to run 75 minutes later every day, the daily period of running was occurring in the daytime in less than 2 weeks. The period of running can be seen to scan the day more than three times during the 70-day period from November 13 through January 20.

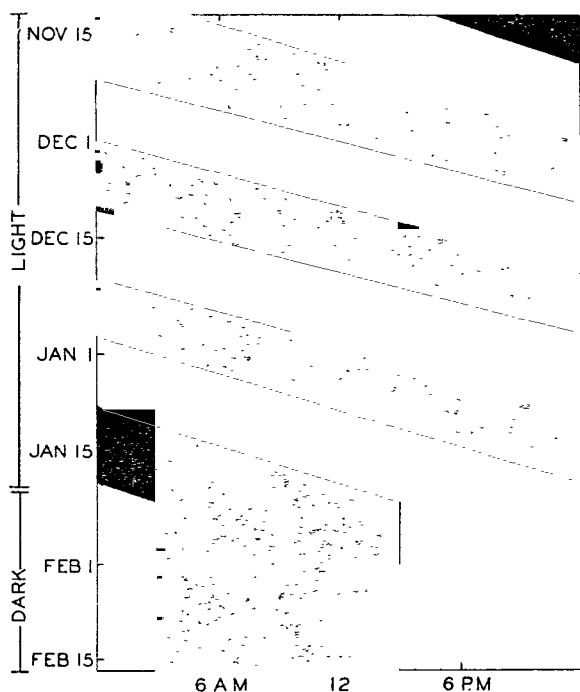


FIGURE 3.—Shaded area indicates time of day of running activity of one male white rat during 70 days in dim, constant illumination followed by a 25-day period of continuous darkness.

When, at the end of this time, the rat was placed in darkness (the last 25 days in fig. 3), the rhythm became an accurate 24-hour one, the rat running at the same time each day. In other words, the rat appeared able to indicate accurately the time of day by its running only when it was in continuous darkness.

In the bean seedling not only may the sleep rhythm often have natural periods a little different from 24 hours in constant darkness at ordinary room temperature, but the length of the periods seems to be inherited; some genetic strains have longer-period natural rhythms in these constant conditions than others. One strain whose rhythmicity has been studied very extensively possesses a 28-hour cycle.

The clocks of man are simply instruments with built-in cyclic changes corresponding to the length of the natural daily cycle, and by their appropriate divisions into hours, minutes, and seconds, enable us to know at any given instant at just what point in the daily cycle we have arrived. The daily cycles of living things are often referred to as depending upon "biological clocks," since the daily rhythms of all living things imply the possession by the organism of a means of measuring accurately the period of the day.

By the same token, living things seem also to possess a basic timing mechanism indicating the lengths of lunar periods, or a "lunar clock." And since a number of living things are known also in constant conditions to measure periods of annual length, they appear also to have "annual clocks." These last two kinds of "clocks" we treat in our annual calendars with their monthly divisions. Therefore, living things behave as if they possessed both "clocks" and "calendars" by means of which many vital processes are appropriately timed even in the absence of such well-known daily, monthly, and annual changes as those of illumination and temperature.

The characteristics of the rhythmicity in living things of the kind that have just been described led many investigators of the phenomenon many years ago to the conclusion that living things possess within themselves clock mechanisms that would permit them, when isolated from all environmental changes which were conceded to be able to influence them, to measure off accurately periods closely corresponding to the lengths of the solar day, and other natural periods. In other words, there was postulated to be operating in living things a completely *independent* complex of rhythms which paralleled in their natural periods the complex known for the external physical environment. This view was entertained despite the fact that certain skeptics of this view had demonstrated over the years that there were circumstances in which the rhythms of living things could not be shown in constant conditions. Stoppel could not observe them in a basement in Iceland during the time of the midnight sun; Cremer could not find them in a deep salt mine in Germany, nor Hempel and Hempel in Lapland during the time of the midnight sun. The investigators who discovered these very interesting exceptions claimed or implied that the rhythm in the bean seedling or insects which they used depended upon rhythmic changes in the environment which still, in some manner, pervade all ordinary so-called laboratory constant conditions. Under these special circumstances, the rhythmic external factor was postulated to be not present.

But biologists, like other scientists, are human and often not always quite as fully objective as is commonly believed. It was for them easier to rationalize objections to the way an experiment was conducted, or to claim correctly that no one had yet confirmed the experiment, than to abandon a hypothesis which, except for these little disrupting facts, provided a consistent view.

At any event, all the evidence at hand seems to suggest the possession by living things of a rhythmic phenomenon superficially resembling a recording system with about one complete circuit per day. This system appears capable of having any form of behavior pattern impressed upon it, whereafter it keeps repeating this pattern until either it fades away or some new pattern is made to replace it.

Such a resemblance to a recording system was lucidly shown by Professor Bünning for the bean seedling. If we have a bean seedling displaying in constant low light a daily sleep rhythm, drooping its leaves at night, and now give it a brief brighter light stimulus during the nighttime phase, we see that not only does the light cause a momentary brief elevation of the leaf but now the plant continues to do it day after day at the same time even in constant darkness. From the standpoint of rhythmicity, the basic question is, what keeps the recording system going at an essentially uniform speed, sometimes quite precisely one circuit per day? One widely held view, as has been mentioned earlier, is that the living thing possesses within itself some machinery for measuring off quite independently from the environment periods of time, but since all known living machinery is predominantly chemical in nature, this would clearly have to depend upon the rates of chemical reactions.

There is a very general rule, the van't Hoff rule, applying equally to chemical reactions and to living processes, which states that as the temperature rises, the rate of chemical processes speeds up, and as we lower temperature, the rate slows down. The rate of biological processes usually more than doubles for every 18° F. rise in temperature. This law is the basis of the universal use of refrigerators to reduce the rate of food spoilage or bacterial decay. Now if the rhythmic timing mechanism were biochemical and wholly inside the organism, one would expect a speeding up of the rhythm with increasing temperature, and a slowing down with decreasing temperature. For example, if at 70° F. the period of the rhythm was 24 hours, at 90° F. we would expect it to be about 8 or 10 hours and at 50° F. about 50 hours. When we studied critically this problem with fiddler crabs about 10 years ago, we found to our amazement that through a wide range of temperature the period of the rhythm remained the same, precisely 24 hours. The animals had available some method of time measuring that was independent of temperature, a phenomenon quite inexplicable in any currently known mechanisms of physiology, or, in view of the long period lengths, even of chemical reaction kinetics. Following this discovery it was rapidly shown in our laboratory and in those of others that the daily cycles of other animals and plants were similarly temperature independent. The most spectacular recent demonstration of temperature independence involved a study of dried plant seeds. These have been shown to have an annual rhythm in their capacity to germinate even when stored in constant conditions. Bünning and his associates in Germany recently found that dried seeds showed an accurate annual rhythm whether they were stored at 3° below zero F. or at 120° F. At the former temperature, 35° below the freezing point of water, all vital processes would normally have been expected to be at least temporarily halted.

There are also many powerful drugs and poisons which are known to slow down living processes greatly. One of these is cyanide. None of these ordinary depressing drugs, though the doses may be so great as barely to permit the organism to survive following their removal, will in any manner slow down the rhythms. These extraordinary relative immunities of the rhythms of plants and animals to temperature and drugs certainly begin to strain one's confidence that they are wholly inside the living things. And what sort of autonomous series of reactions could possibly be imagined in which the organism, with all its transformations occurring during that year, could possibly provide information as to just when one year had elapsed, even when not harrassed by drugs or freezing temperatures? Even a comparably resistant 24-hour cyclic mechanism is virtually impossible to conceive in any conventional terms of chemistry or biology.

And philosophically it is very difficult to imagine the living organism as possessing an internal clock, wholly independent of all external factors, of the remarkable absolute precision it must have to account for the rhythmicities. On the other hand, if the organism had, even while in the so-called "constant conditions," daily, lunar, and annual rhythms being impressed upon it by external physical factors, these might constitute the fundamental clock system which could pace, or provide reference rhythms, for the labile biological rhythms possessing approximately the same frequencies. Some biologists, forgetting that they first made the quite arbitrary assumption that the biological rhythmic processes and the clocks which time them are one and the same thing, claim as already proven that the clocks need no external information through the demonstration that the rhythms are freely modifiable and often have periods other than the natural ones. It might be recalled, however, that using our ordinary pocket or wrist watches, set to the correct time of day and running at their usual speed, we can readily change the pattern of a precise daily behavior pattern, or time accurately a 22- or a 26-hour rhythmically recurring event, both of which capacities we would probably lose forthwith were our watches suddenly to be taken from us.

The temperature independence of the frequencies of the organismic rhythms was a very difficult fact for physiologists to credit, especially since the general consensus was that the timing of the cycles was exclusively inside the organisms. This was an apparent evasion of a time-honored rule of physiology. But this spectacular fact became demonstrated unequivocally so easily and in so many laboratories that it was necessary that the problem be faced. The reaction of most investigators was to begin to postulate various kinds of hypothetical mechanisms by which organisms might have internal clocks that would perhaps do this. A few such speculations have been advanced in the literature of the past two years.

In our laboratory, where the complete *temperature independence* was first demonstrated and its implications stressed, our reaction was different from that of the others. It seemed to us that the phenomenon was so extraordinary that perhaps still another of the sacred tenets of physiology was invalid. This other one was the fundamental premise of the experimental physiologist that when he keeps his organisms in constant illumination, temperature, humidity, and all other factors he has conceded to influence them, the organism is truly in constant conditions. So time revered was this view that even to question it seemed a sacrilege. And we knew when we did it that the opposition of tradition would be tremendous to overcome.

In a sense the view that we took was simply a more sophisticated one of the type taken by the numerous skeptics of a decade or more ago, when told of the persistence of rhythms in constant conditions. They doubted that the investigator had really controlled all daily fluctuating factors as well as he thought he had.

An experiment we performed with oysters had raised similar doubts in our minds, too. The U.S. Fish and Wildlife Service had shipped us a batch of healthy oysters they had collected in New Haven Harbor. Since the tides are, you recall, of lunar-day frequency, we studied in the oysters the time of lunar day of maximum opening of their shells for feeding in pans of sea water in a photographic darkroom in Evanston. For about the first two weeks they opened their shells most at the time of high tide in New Haven Harbor; then they appeared to forget their home tidal times and for the next two fortnights they opened their shells almost at the times of lunar zenith and nadir in Evanston, a 3-hour time change. These new times were the times of maximum gravitational attraction by the moon as it produces the well-known lunar tides of our atmosphere.

In order to examine further the question as to whether the external factors were actually controlled, we sought a biological process which was common to every living thing. For this we selected metabolism. Metabolism underlies all animal and plant activities and thus we were no longer limited to the study of special forms. The rate of metabolism could be measured by the rate at which the living thing used oxygen. Also, the higher the rate of metabolism, other factors being equal, the greater the amount of spontaneous activity displayed by an animal, and hence we could also measure metabolic rate by studying spontaneous activity. It did not require a very long initial study to demonstrate beyond all reasonable doubt that living things, even while in so-called constant conditions, had access to outside information as to the time of day (or position of the sun), time of lunar day (or position of the moon), time of lunar month, and even time of year.

I shall not try my readers with either the detailed methods of study or the mathematics of the analysis, but shall simply summarize for you some of the principal facts. The most complete of our studies have been done on young potato plants, small pieces of potatoes with sprouting eyes prepared as illustrated in figure 4. Occasionally, while being studied in our recording apparatus, they even developed new potatoes. Potatoes were selected for this study for two reasons: (1) The potato tuber is essentially a generous reservoir of stored food, and hence there was no problem of feeding the organisms while they were sealed for long periods in constant, dark conditions; and (2) these seemed about as inauspicious a living thing as one could expect to find as far as rhythms were concerned. Briefer, parallel studies with other plants and animals have suggested that what we have found for the potato holds in a general manner for all other living things as well.

It is well known that there are solar and lunar tides of the atmosphere. These are reflected in rhythms of barometric pressure change. In the daily cycle (the upper curve in fig. 5A), the pressure, on the average, always rises during the early morning hours to a high about 10 o'clock and then falls to the low point of the day, during the middle to late afternoon, the time of the low point depending on the time of year. This is a precise average 24-hour rhythm. The potato has similarly a precise average 24-hour cycle of metabolism (the solid line of the lower curves in fig. 5A) with a minimum rate at midnight and a maximum rate at 6 in the afternoon. This average daily cycle can be shown to include the average of two kinds of daily oscillations: the dashed AA'A'' and the dotted BB'B'' ones in figure 5A. Both the barometric-pressure cycles and the potato cycles exhibit irregularities from day to day. The barometric-pressure cycles are distorted by

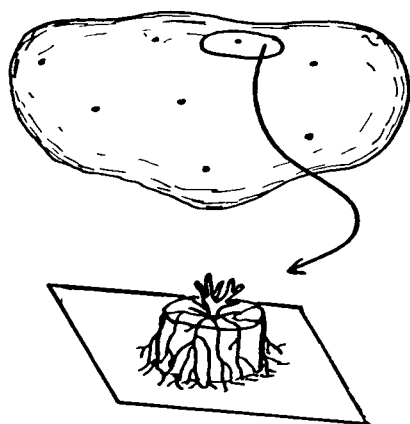


FIGURE 4.—Method of obtaining the potato plants used in the study of metabolic cycles.

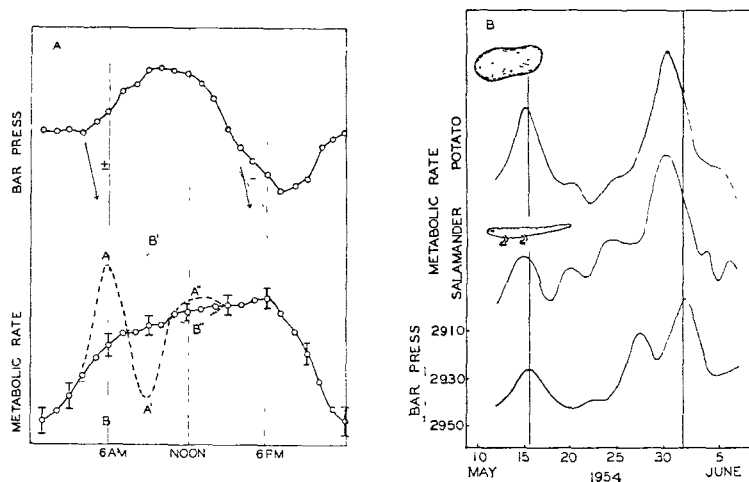


FIGURE 5.—A, The general form of the daily barometric pressure cycle during a summer month (upper curve), and the mean daily cycle of potato O_2 consumption (lower curve). B, A comparison of the day-to-day changes in metabolism of both potatoes and salamanders with the concurrent barometric pressure changes.

large changes due to still unknown forces, which are associated with weather changes. The important fact for us here is that the potato is informed of how fast the pressure is rising in the morning and falling in the afternoon. This we know, first, because how high, or how low, the potato metabolism is at 6 in the morning (points A or B fig. 5A) of any given day is simply related to how fast the barometric pressure was changing from 2 to 6 the preceding morning. And, secondly, how high the rate of metabolism in the potato is at 6 in the evening of any given day is related to how fast the barometric pressure was changing from 2 to 6 the preceding afternoon.

Hence the potato in the form of its daily metabolic fluctuation, even in constant conditions of pressure, through being hermetically sealed in rigid containers, is in effect informing us through indicating in its metabolic changes what the weather distortions were in the regular pressure cycle of yesterday. And whatever the means by which this information reaches the potato, the same information is providing the potato, figuratively speaking, with information as to what the weather-associated barometric pressure will be the day after tomorrow, by the height of the afternoon peak of metabolic rate. This is tending to trace out the form of the barometric pressure changes but doing so two days in advance. This is illustrated by the month-long study of potatoes and salamanders shown in figure 5B. Notice how both kinds of living things generally vary inversely with the barometric pressure change (bottom curve), but both tend to anticipate the pressure changes by an average of 2 days. In fact, every living

thing studied in our laboratory during the past 3 years—from carrots to seaweed, and from crabs and oysters to rats—has shown this capacity to predict very safely beyond chance the barometric pressure changes usually 2 days in advance. It is interesting to contemplate the problem of a meteorologist sealed, incommunicado, for weeks or months in constant conditions, and asked to give 2-day weather predictions—or for that matter even to tell you the weather today.

The potatoes also indicate to us that they are, while sealed in constant conditions, obtaining information about another well-known environmental daily rhythm, namely that of high-energy background radiation. This is so penetrating that it pervades all ordinary buildings and containers. This radiation is highest about 6 in the morning and lowest between noon and 6 p.m. The daily range, or cycle amplitude, in the radiation, though averaging about 2 percent, varies greatly and unpredictably from day to day. The potato cycles also show variable total range, or amplitudes, from day to day. But the amplitude of the potato cycles on a given day is very clearly related to the amplitude of the background radiation cycle the day before. The greater the fluctuation in radiation yesterday, the greater the fluctuation in metabolism today.

The potato sealed in constant conditions also obtains information as to the outdoor air temperature. As clearly seen in figure 6, the higher the outdoor temperature up to about 57° F., the higher the amplitude of the daily metabolic fluctuations. This relationship is reversed for higher temperatures. As everyone knows, there are clear daily and annual rhythms in air temperature.

The potato in constant conditions also exhibited a lunar monthly rhythm of metabolism during a full-year period of study. As seen in figure 7A, the rate was lowest at the time of new moon and highest

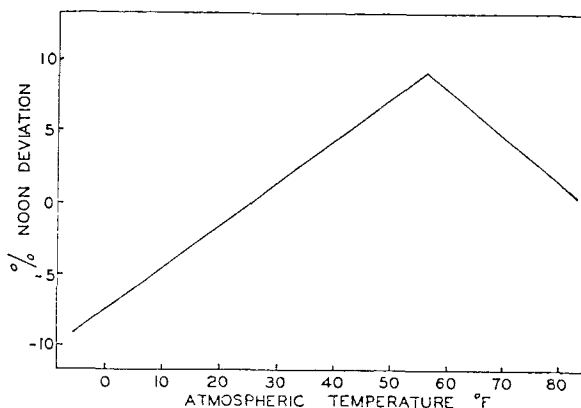


FIGURE 6.—Relationship between percentage change in metabolic rate of potatoes between midnight and noon, and the outside air temperature.

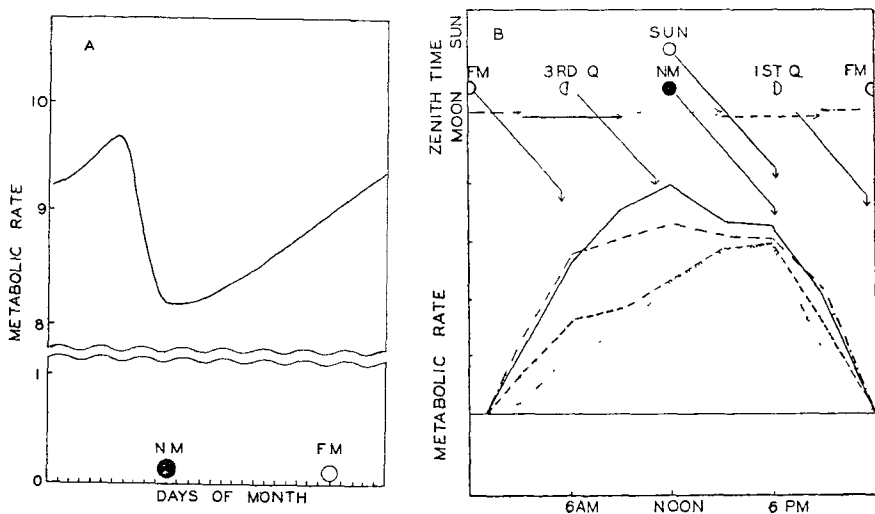


FIGURE 7.—A, The variation in average metabolic rate in the potato with time of the lunar month. B, The change in form of the average daily metabolic fluctuation with day of the month.

at the time of third quarter. The rate of metabolism was 20 percent higher at third quarter than at new moon. There was also a monthly cycle in the form of the daily cycles. As seen by the dotted curve in figure 7B, the daily cycles were depressed during the morning hours, at the time of new moon, and, as shown by the solid line, quite symmetrical and high, with a maximum at noon, at the time of the third quarter. The sun is, obviously, always at its highest point in the sky at noon. The time of day the moon is highest depends on the time of month. Over full moon, it is midnight; over new moon it is noon. These changes in the form of the daily cycles through the month seem logical if we think of the sun and moon having qualitatively the same effect on metabolism, the maximum accelerating action of each on metabolism occurring about 6 hours later than the time it reaches its zenith in the sky.

An annual cycle in the form of the daily cycles was also found to exist in constant conditions. The average monthly values for two years of study are shown in figure 8A. The cycles were lowest in amplitude in January and February, and highest in September, October, and November during both years. There was also an annual cycle in general metabolic rate in the constant conditions (fig. 8B). The highest rate occurred in May, and was about twice that seen in the lowest month, October.

Collectively these facts provide incontrovertible evidence that even when we have thought we have excluded all forces influencing the living things, there is, nonetheless, cyclic information, unquestionably

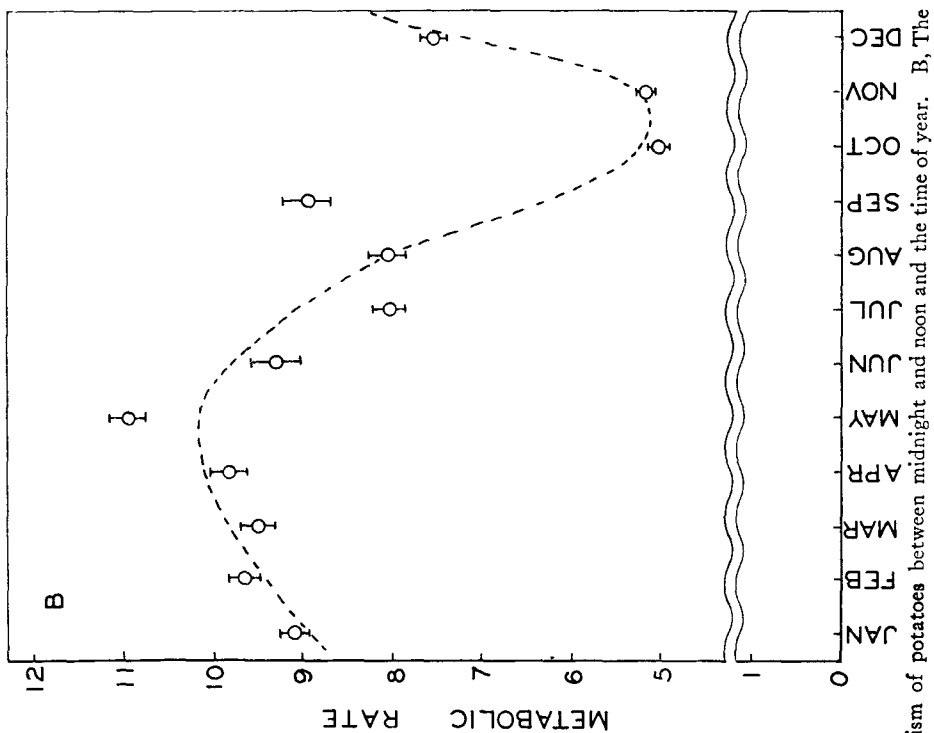
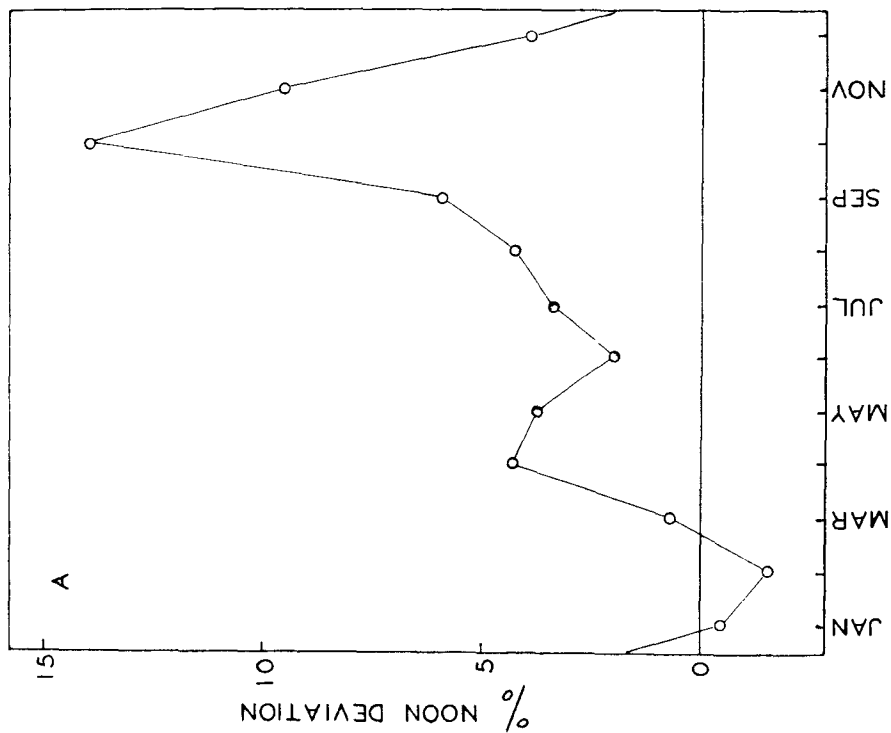


FIGURE 8.—A, The relationship between the percentage change in metabolism of potatoes between midnight and noon and the time of year. B, The variation in average metabolic rate with time of year.

with all the natural periodicities of the atmosphere imbedded in it, still impressing itself upon the organism. Living things might conceivably possess inherited, regular rhythms, but it is quite inconceivable that they are born with an inherited plan of all the erratic temperature, barometric-pressure, and background-radiation fluctuations which are to occur during their lifetime. So far we don't know what the specific nature of the factor or factors may be which are directly effective on the living organism. This is one of the most important and exciting problems before us in our continuing research.

But to suggest further that the forces involved in our problem may be in part determined by other forces arriving on our earth even from outside of our own solar system, we have obtained some striking similarities of our biological metabolic rhythms, with fluctuations in cosmic radiation raining on our outer atmosphere predominantly from distant outer space. This discovery was the outcome of a comparison of metabolic daily cycles in potatoes, seaweed, and fiddler crabs during the spring and summer of the two years, 1954 and 1955. Between these two years, the daily metabolic cycles of all three species seemed to have, in good measure, turned upside down. In the fiddler crabs, for example (as shown in the upper solid curve in fig. 9, the highest rate of metabolism for the day in July 1954 was about 2 p.m.; in July 1955, as seen in the lower solid curve of figure 9, this was near the time of day of the lowest rate in the daily metabolic cycles. In searching for a possible difference that might have occurred in some subtle external physical factor between the two years, some data upon the fluctuations in cosmic radiation occurring at the specific times of these

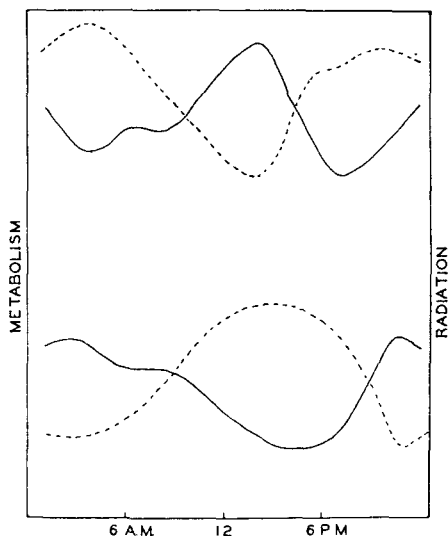


FIGURE 9.—Comparison of the average daily cycles of cosmic radiation (broken lines) and fiddler crab metabolism (solid lines) for a single summer month in each year, 1954 (upper pair of curves) and 1955 (lower pair of curves).

studies were lent to me by Professor Simpson of the Enrico Fermi Institute of the University of Chicago. It was clearly evident that just as the crab daily cycles seemed to have been inverted between these two specific periods of study, so had the cosmic-ray cycles for the same two periods (the two broken-line curves). And furthermore, the general forms of the crab and radiation cycles were striking mirror images of one another. Similarly with the potatoes and seaweed, the forms of the metabolic cycles we had measured seemed clearly related in some manner to the cosmic-ray cycles.

It is obvious that the specific forms of these cosmic-ray cycles could not have become evident to the living things in terms of fluctuations in any physical factors which are commonly conceded to influence them, such as light, humidity, and temperature. This would hold true even were the organisms exposed to the natural fluctuations of an open meadow. Clearly then, there must be still unidentified physical factors affecting life. And it now seems reasonable to postulate that these latter factors are very important to the living things in the timing of their rhythmic processes, or, in other words, in the operation of their clocks and calendars.

The thesis supported in this article, namely, that during the timing of cycle lengths of the rhythms in animals and plants in so-called "constant conditions" the organisms are still continuously receiving from the external environment information about the natural geophysical cycles, removes some of the romantic glamour inherent in the alternative view, that all living things must possess within them uncannily accurate clocks capable of measuring, independently, periods ranging in length from the day to the year. On the other hand, its implications are tremendous with respect to the potentialities involved through the demonstration that living things are sensitively responding to additional kinds of stimuli at energy levels so low that we have hitherto considered the living organism completely oblivious of them. These latter potentialities may soon loom importantly in many areas of biology and medicine, especially in such problems as animal navigation and behavior.

The demonstration that the physical environment of living things is organized temporally in terms of still unknown subtle and highly pervasive forces which the living organisms can resolve encourages one to speculate that there may be some comparable subtle and pervasive spatial organization of the environment which is contributing at least in a small way toward accounting for geographical distributions or periodic migrations of organisms.

The Survival of Animals in Hot Deserts¹

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MY AIM in this lecture is to consider the difficulties which confront animals living in hot dry environments, and to try to answer the question as to why some animals are more successful than others in overcoming them. The problems for all are the same: how to prevent desiccation and how to keep cool. But the solutions are various, and depend upon the morphological and physiological equipment of the animals concerned.

The process of keeping cool may involve loss of water. But water in hot climates may be in short supply, and in any case water loss is necessarily incurred in such vital processes as respiration, excretion, lactation (in mammals), egg production, and so forth. A conflict is therefore immediately apparent between the necessity to conserve water for vital processes and to transpire water for cooling. It will be part of my purpose to see how these opposing needs are brought into equilibrium in different kinds of animals.

Now the problems confronting animals in hot deserts are essentially the same as some of the problems experienced in a less acute form by all terrestrial animals during their evolution from water to land life. We must therefore see the former problem in a wider setting, and take the discussion in two stages. First, we may review, in fairly general terms, the problems of terrestrial life, and note how different groups of animals have tackled them. Second, in the light of this information, we may consider in greater detail the solutions of the more acute problems posed by extreme terrestrial conditions.

There have been major invasions of the land by three great phyla—vertebrates, arthropods, and mollusks—as well as minor invasions by other animals such as flatworms and annelid worms. Within the arthropods there has certainly been more than one invasion. Insects and spiders probably emerged separately; crustaceans certainly

¹ Inaugural lecture given in the University College of Rhodesia and Nyasaland. Reprinted by permission of the College and the Oxford University Press.

emerged more recently, and in several distinct groups. Because of their different evolutionary histories, each of these groups of animals has a different set of potentialities for life on land. We shall try to assess the significance of these differences.

THE PROBLEMS OF LAND LIFE

What are the problems concerned in the evolution of a land fauna? The comparatively rare medium, air, affords no support for the body, and calls for a complete reorganization of the means of locomotion. Gills, which are very efficient organs of respiration in water, collapse in air and present too small a surface for the uptake of oxygen, so that respiratory organs have to be remodeled. The respiratory membranes themselves, however, must be kept moist and thin, because oxygen does not diffuse rapidly enough through a dry integument.

Changes in metabolic machinery, too, are necessary. Thus, the waste products of nitrogen metabolism can most economically be excreted as ammonia, and aquatic animals use this method, for although ammonia is highly toxic, plenty of water is available to flush it away. On dry land, water is not so plentiful, and ammonia cannot be used.

The simple process of discharging large numbers of reproductive cells into the environment for external fertilization must be replaced by internal fertilization, which in turn demands complicated behavior patterns to insure association of the sexes. The eggs of land animals, once fertilized, cannot be discharged and left to fend for themselves. They would dry up. Therefore they must be enclosed in impermeable shells and provided with food and with metabolic machinery for converting ammonia into nontoxic and preferably insoluble substances which can be stored during the period of incubation.

The fact that air is hardly ever saturated with water vapor, and is often rather dry, means that a terrestrial animal is in danger of losing water continuously by evaporation.

Finally, the terrestrial environment is one in which changes in temperature and humidity occur over a much wider range and more rapidly than they do in water. These changes must be tolerated, controlled, or avoided.

Let us now consider how these problems have been solved by different kinds of animals.

RESPIRATION

The vertebrates solved the problem of respiration in two stages—first the amphibians developed an internal lung, which was rather inefficient and had to be supplemented by cutaneous respiration. This involved a moist skin. Then the reptiles perfected the lung and consequently could afford to develop an impermeable integument.

Respiration in land arthropods is carried out in a number of different ways. Insects, perhaps the most successful group, have

evolved the highly efficient tracheal system. This consists of numerous branching tubules leading air directly to all parts of the body from a small number of external openings, the spiracles, which are capable of being closed. Occlusion of the spiracles reduces loss of water from inside the tracheae when the insect is at rest and oxygen is required only in small quantities. Because of this respiratory system it has been possible to reduce cutaneous absorption of oxygen to a minimum, so that the integument need not be permeable to water and is, in fact, efficiently waterproofed. Although the total surface area of the animal is of the order of 5,000 times greater than that of the spiracular openings, as much as 60 to 70 percent of the total water lost by transpiration passes through the spiracles.

Spiders, another very successful group of arthropods, have not developed the tracheal system very effectively, and they rely upon "book lungs" (the term is self-explanatory) situated in pits whose openings can also be closed. The system is good enough to provide for normal oxygen requirements, and the integument can be waterproofed; but spiders cannot indulge in long bursts of great activity because they rapidly run out of oxygen.

Another class of arthropods with pretensions to land life are the Crustacea, and these animals present a very different picture. They have never evolved an effective respiratory system for use on land. Woodlice absorb oxygen through external, leaflike organs which are but little modified from the gills of their aquatic relatives. Transpiration from the gills constitutes some 40 percent of the total transpiration, and the absolute rate of transpiration is much higher than it is in insects. Some woodlice, indeed, have developed short bunches of internal tubules in the gills, and these are the most "terrestrial" of the group. But in all of them absorption of oxygen also occurs through the general body surface, and the integument is much more permeable to water than is that of insects. This is true only in humid air, however; otherwise the outer layers of the skin become too dry, and measurements show that the effect of exposure to very dry air may be to cause death by asphyxiation rather than by desiccation (Edney and Spencer, 1955).

NITROGEN EXCRETION

As regards nitrogen excretion, an interesting relation between the availability of water in the habitat (particularly during embryonic development) and the nature of the end product has been pointed out by several authors (Needham, 1929; Delaunay, 1931).

We have seen that in land animals the waste products of nitrogen metabolism cannot be excreted as ammonia because this is a highly toxic and highly soluble substance. More wasteful methods have to be adopted, and ammonia is converted into urea, uric acid, or other

product even though this means wasting valuable carbon. Ammonia contains no carbon, urea contains one atom of carbon to every two of nitrogen excreted, and uric acid contains five carbon atoms for every four of nitrogen excreted. But there is less hydrogen in relation to nitrogen in a molecule of urea than in ammonia, and still less in uric acid. By substituting urea or uric acid for ammonia, water is saved, and this is the most important consideration. Furthermore, both urea and uric acid are nontoxic, and the latter is also nearly insoluble in water, so that no free water is needed for its elimination.

The principle may be illustrated by a few examples. Lungfish are normally ammonotelic, that is, they excrete ammonia; but when they aestivate in dry mud, and water is short, they excrete urea. The semiterrestrial Amphibia are ureotelic (excreting urea), but their larvae, which are fully aquatic, excrete ammonia, and the African genus *Xenopus*, which is aquatic in the adult stage as well, remains ammonotelic throughout its life. Birds and reptiles are uricotelic (excreting uric acid). They develop the necessary metabolic machinery by necessity in the egg stage, when insoluble uric acid has much to be said in its favor, and retain the system throughout their lives. Mammals, during their embryonic stages, have the advantage of a good supply of water in the blood of the parent, and they use urea as the end product of nitrogen metabolism throughout life. According to Needham (1935), gastropods exemplify the principle very well—marine and fresh-water forms store but little uric acid, intermediate littoral forms store rather more, and terrestrial forms most.

Insects excrete uric acid. This process may again have been imposed by the cleidoic egg, but it serves these animals in the adult state remarkably well, and insects which live in dry surroundings lose hardly any water as a result of nitrogen excretion. Spiders use a similarly insoluble nitrogen compound, guanin, which serves the same purpose.

Nitrogen excretion, then, is one of the numerous examples which demonstrate evolution at a physiological level. But, like so many generalizations in biological science, the principle does not cover all the known cases. Thus woodlice, which are terrestrial Crustacea, and which might therefore be expected to excrete urea or even uric acid, do not do so. Most of their waste nitrogen is ammonia. One wonders why, particularly as the enzyme chain leading to the formation of uric acid is present, for indeed a little uric acid is formed, though more is found in the fresh-water genus *Asellus* than in terrestrial isopods.

TRANSPIRATION

We may now consider another source of water loss associated with life on land: transpiration from the general body surface. In this

connection the significance of size, which will increasingly concern us in what follows, becomes apparent.

In large animals little importance need be attached to the prevention of water loss by evaporation, because a given rate of evaporation per unit area can proceed for a longer time in a large animal than in a small one before the total water content falls to a lethal level. A flea could tolerate a transpiration rate of 5 mg./cm.²/hour for about 15 minutes before losing 10 percent of its water, but a man could tolerate 4,500 times this rate of loss for a similar period and suffer the same proportional loss of water.

It is not surprising, therefore, to find that insects have developed a highly efficient method of waterproofing their integument. Insects have a very long terrestrial history, and their origins are obscure, but in this group physiological adaptations have been perfected and refined as far as possible within the general arthropod pattern. The integument has been waterproofed by means of a very thin but probably continuous layer of a waxlike substance composed of a mixture of paraffins and alcohols with carbon chain lengths from about 8 upward. Since Wigglesworth (1945) first demonstrated the presence of these cuticular waxes, there has been much work and speculation devoted to finding out their nature and properties. At first it was thought that they underwent a rather sudden physical change, which permitted much higher rates of transpiration above a characteristic critical temperature. This was held to represent a form of temperature control. However, recent work suggests that there is no sudden increase in permeability with temperature (Holdgate and Seal, 1956; Mead-Briggs, 1956), but a gradual one over the range, and that at biologically significant temperatures the rate of transpiration is too low to contribute greatly to cooling.² There is still very much to be discovered about the nature of these waterproofing substances. We do not even know whether the rise in permeability with temperature is due to a progressive "melting" of the constituents or to simple physical properties known to be associated with activated diffusion through inanimate membranes, or both. However, it is true to say that if the insect integument were permeable, no amount of water conservation by other means would be of any avail.

It is instructive to compare the situation in insects with that in woodlice, whose evolutionary history is very different. Woodlice arrived on land comparatively recently—the earliest fossils date from the Upper Eocene, some 60 million years ago—while insects occur as far back as the Devonian, some 300 million years ago. Woodlice, though they are the only crustaceans whose entire life is spent on

² Since this was first written, Beament (1959) has obtained further evidence in favor of a "critical temperature."

land, are still limited by crustacean anatomical and physiological systems. No wax layer has been successfully demonstrated in the integument; neither does the latter show any increase in permeability with rising temperature. Transpiration rates are generally a good deal higher than in most insects.

KEEPING COOL

Associated with transpiration is still another problem posed by life on land—that is the problem of existence at extreme temperatures. There are several ways of dealing with high temperatures. They may be avoided by living in a cryptozoic niche below the ground, under crevices, in caves, and so forth. This procedure is open only to small animals and is, in any case, a confession of failure. Alternatively, they may simply be tolerated, and this is one of the best solutions for small animals. Thus some insects can withstand temperatures as high as 60° C. (140° F.) for 20 minutes, and many can withstand temperatures well above 40° C. (104° F.) for long periods. Neither of these devices involves loss of water.

The most satisfactory solution is to control the body temperature at a fixed level, as the higher vertebrates, birds and mammals, have done. This of course involves loss of water by transpiration, and the solution is open only to animals above a certain size, as the following considerations show. Assuming that each square meter of the surface of an animal must evaporate 0.6 kg. of water per hour to maintain the temperature constant in warm dry air, a value which has been found for animals weighing from 96 to 16 kg. (Dill, Bock, and Edwards, 1933; Adolph and Dill, 1938), then the percentage of the total body weight lost per hour can be calculated approximately, and the answer varies from 0.77 percent (camel) to 105 percent (woodlice) (fig. 1). Clearly no animal can lose 105 percent of its weight per hour for long, so that this method of keeping cool is available only for large animals.

A rather unsatisfactory compromise, open to small animals with permeable skins, is to use the evaporation of water to cool the body for short, critical periods. This is in no sense temperature regulation; it is the inevitable result of having a permeable skin, for at high temperatures the rate of transpiration rises owing to the greater drying power of the air, and the difference between body temperature and ambient temperature is therefore greater. Such an effect has been observed in several land animals, including amphibians, mollusks, worms, and woodlice.

WATER ECONOMY—A SYNTHESIS

Let us now attempt something of a synthesis, in order to appreciate the significance of these various sources of water loss. In partic-

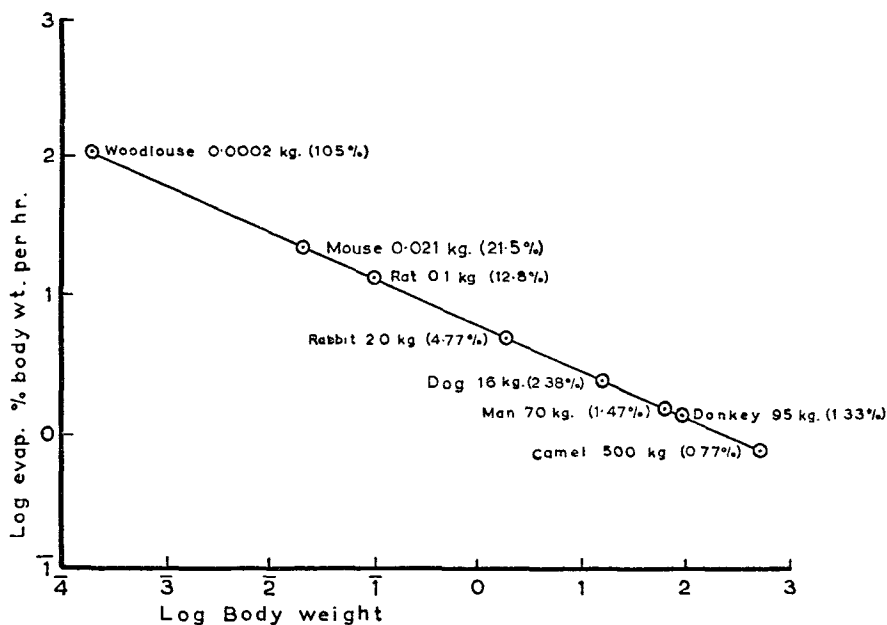


FIGURE 1.—The relation between body weight and the amount of water which must evaporate per hour from the body to preserve a constant temperature in desert conditions. (Date in part from Schmidt-Nielsen, 1954.)

ular we want to know whether or not each source of loss is inevitable, and whether it is harmful or beneficial.

Loss of water associated with nitrogen excretion is the only one that has no possible compensation. The heat loss involved in evaporation is in this case of no use to the animal, for evaporation occurs at a distance from the body.

Water loss from the respiratory surfaces is inevitable. It may be reduced to a minimum if the respiratory surfaces are tucked away within the body and are capable of occlusion, as they are in insects and spiders; but where the respiratory membranes are external, as in woodlice, or where there is a ventilated respiratory system, as in vertebrates, the loss of water is considerable. Most land vertebrates are compelled to ventilate the respiratory membranes on account of their size, and in mammals and birds because of the high metabolic rate necessary to support a constant high temperature. But this source of loss may have its compensations, for evaporation of water occurs at the surface of the respiratory membranes, and therefore withdraws heat from the body itself.

A small loss of water by transpiration from the general body surface is also inevitable, for no integument is entirely impermeable to water. In small animals surface transpiration must be reduced as far as possible if the animals are to exist in dry habitat. If trans-

piration is not reduced, surface cooling may occur and be taken advantage of, but the animals will be confined to the cryptozoic niche. Larger animals can afford surface transpiration, and in normal environments this may be used as a temperature-regulating mechanism.

It seems, then, that three interdependent variables have to be considered: an animal's size, the nature of its respiratory system, and the permeability of its integument. We should expect that while certain combinations of these factors would permit life in fully terrestrial conditions, other combinations would forbid it. Thus small size combined with an oclusible respiratory system and an impermeable integument is a satisfactory combination for land life; large size, a ventilated respiratory system, and a permeable integument is also satisfactory, but other combinations are not. To these interdependent factors must be added a number of others which are not interdependent—that is to say, their optimum value lies always at one end of the range. Thus it is always advantageous in hot dry surroundings to lose as little water with nitrogen excretion as possible, and it is always advantageous to have a high upper lethal temperature. Optimum values of these factors are, of course, not always attainable. The evolutionary history of an animal may forbid it. Thus a mammal owes its success to homoeothermy—constant temperature—and to permit the body temperature to rise as high as it may in some insects would adversely affect the whole organization. When this happens, the delicate mechanism of the brain is the first to suffer.

Before we examine the validity of these principles in real situations, something must be said of the other side of the picture, that is, gain of water. This may be achieved by straightforward drinking, when water is available, or by taking in water with the food. A few animals can absorb water by rectum (some woodlice do this) or through the skin. But these are comparatively unimportant for our purpose.

A few arthropods can absorb water vapor from unsaturated air. This is a remarkable and rather rare phenomenon, but one which may have a wider significance in water conservation than is apparent. It has been reported in ticks and certain beetle larvae in air with a relative humidity of 80 percent or above, and in flea larvae in even drier air (references in Edney, 1957). Now the osmotic pressure of the body fluids of insects and ticks is in equilibrium with air at about 99 percent relative humidity. There can therefore be no question of water flowing down an osmotic gradient. The mechanism of this active transport has not been demonstrated, but a further piece of information may be relevant. There is some evidence, obtained by the use of heavy water, that water in the body fluids of an insect is in continuous interchange with water vapor in the air outside. If this

were confirmed, it would seem that besides the known effect of evaporation in removing water from the body, there must be another mechanism drawing it in. Possibly these two mechanisms are at work all the time, the net effect either of uptake or loss, depending upon the relative efficiency of the two processes in a given individual under given conditions. The nature of the inward force, if it exists, and the conditions in which it is apparent, are quite unknown.

Another source of water, an important and a universal one, is the water of metabolism. All animals necessarily produce water when they oxidize food containing hydrogen, and indeed the amount of water produced may be greater than the initial weight of the food. Thus 100 g. of fat, completely oxidized, yield 107 g. of water. This is the reason for the remarkable observation that certain beetle larvae may increase in weight during starvation (Mellanby, 1932). But the process is in no way an adaptation to dry conditions. It is common to all animals. The adaptation consists in conserving, by other means such as we have already discussed, water from metabolism together with water from any other source.

LIFE IN DESERTS

THE DESERT ENVIRONMENT

Let us now consider extreme terrestrial conditions, taking a hot desert as an example. What is known about the physiology of the animals that live there, and what remains to be discovered?

In a desert the surface temperature of the ground is very high during the daytime. It is often higher than that of the air above it, owing to the absorption of radiant energy from the sun. During the night, surface temperatures fall very steeply because the sparse cover of vegetation permits rapid radiation of heat to the sky, and the air is then warmer than the ground. At all times temperatures below the ground and in caves are much less extreme than surface temperatures. Humidity is usually very low, and this, combined with high temperature, leads to rapid evaporation of water from moist surfaces. But because of the great fall in temperature at night, the relative humidity rises and evaporation is greatly reduced. If the surface temperature falls sufficiently low, dew may be formed. In these circumstances, during the daytime heat is gained by an animal largely by radiation from the sun and from the ground, but also significantly as a result of metabolism, especially in large animals. Little heat is gained by conduction from the ground. The air temperature may be above or below that of the animal's surface and heat flows by conduction accordingly. Heat is lost by evaporation of water and by conduction to the air if the latter is below skin temperature.

MAMMALS

There is by now a good deal of information about mammals which live in deserts, reviewed by K. and B. Schmidt-Nielsen (1954). In these animals the effect of size on water economy becomes at once apparent. Small species such as the African jerboa or the American kangaroo rat can avoid extremes of temperature and dryness by living in burrows. They do so and emerge to feed at night only. On the other hand, being mammals they must lose water both in respiration and in excretion. Yet these animals can exist indefinitely on perfectly dry food and no water. The answer lies in certain quantitative changes in their water physiology, not in the invention of any qualitatively new process. They conserve the water of metabolism better than other mammals in several ways. First, they do not sweat, and their rate of transpiration is less than half that of the ordinary white rat. It seems likely that the commonly observed absence of sweat glands in small mammals receives a general explanation here: it results from the necessity imposed by their relatively large surface to conserve water.

Jerboas lose in evaporation from the respiratory surfaces only half of the water lost by man per unit oxygen uptake, perhaps by exhaling air at a lower temperature so that it requires less water to saturate it. They excrete only very small quantities of very concentrated urine, and they lose very little water with the feces, which are deposited practically dry.

These small animals do not use water to maintain a constant temperature in the desert for the good reason that in air at 40° C. they would have to lose 20 percent of their body weight per hour. But there is an emergency procedure, for if the body temperature approaches the lethal level (about 42° C.) copious salivation occurs, which wets the fur of the chin and throat and thus reduces the body temperature. This can only be effective for a short time, however, because the loss of water is great and soon leads to desiccation of the tissues.

With a large mammal such as a camel it is a very different matter. These animals cannot escape the heat of the day; they must either tolerate it, or use water to prevent a rise in body temperature. Here, therefore, we find a shift in the balance of physiological mechanisms, again only quantitatively, but in relation to the possibilities and limitations imposed by size.

The camel does not store water. It exists for periods of a fortnight or more on dry food alone by tolerating a much greater depletion in body weight than most other mammals can. Thus a camel tolerates a loss of water equal to nearly a quarter of its body weight (100 kg. out of 450 kg.) as compared with something like 12 percent in man.

At the end of such a period of desiccation the camel will drink sufficient water to restore its body weight (but no more) in a few minutes.

How is it that a camel can tolerate a much larger proportional loss of water than a man? In most mammals subjected to high temperatures in dry air, desiccation proceeds slowly while the temperature remains rather constant. But owing to loss of water from the blood, the latter becomes gradually more viscous. This puts extra strain on the heart, which, at a certain degree of viscosity, cannot circulate the blood sufficiently rapidly to carry away metabolic heat to the skin. At this point the temperature rises rapidly and death follows suddenly. The phenomenon has been termed "explosive heat death" by Adolph. In camels, however, explosive heat death is rather skillfully avoided. There is a physiological mechanism, whose nature is so far unknown, which ensures that water is lost from the tissues only, while the blood volume, and hence its viscosity, remain constant. In a camel which lost 50 liters of water, reduction in blood volume was found to be less than 1 liter.

Because of this ability and also because of its relatively small surface area, the camel can afford to sweat and thus to reduce the body temperature. Furthermore it avoids undue stress in this respect by allowing its temperature to vary over a greater range than other mammals do. In man, the daily fluctuation in temperature is about 1°C ., but the camel's temperature falls to 34°C . during the cool of the night and rises slowly throughout the day to as much as 41°C . To raise 450,000 g. through 7°C . needs a lot of heat. Only after this temperature is reached does sweating commence.

The old story that the camel stores water in its hump has by now been decently buried, but it has been replaced by another almost equally fallacious: that the fat of which the hump is composed is essentially a water store itself. As we have seen, it is perfectly valid chemistry to say that 100 g. of fat when completely oxidized yield 107 g. of water. But in order to oxidize the fat and make the water available, extra oxygen must be used, and this involves extra loss of water through the lungs to an amount which just about cancels any gain from the oxidation of fat.

No, the camel's hump is a foodstore, just as any other fat deposit is, but there is an interesting reason for its taking that form. As Schmidt-Nielsen has pointed out, it is curious that in many mammals that live in hot climates, fat is not distributed as a subcutaneous layer, but is restricted to one large deposit. In camels this is the hump, in Indian and Zebu cattle, the same; in fat-tailed sheep it is the tail. Now when water evaporates, cooling occurs by the absorption of heat from the immediate environment. But if the animal's surface is thermally insulated from the rest of the body by a poor heat

conductor such as fat, nearly all the heat absorbed will be taken from the air, and the body temperature will hardly be affected. If the skin is thin, however, with a rich blood supply and no insulating fatty layer, heat may readily be withdrawn from the tissues. The concentration of fat into one depot allows the rest of the surface of the animal to act as a radiator in this way.

Fur is also an advantage to desert animals in preventing overheating, for it acts as a heat barrier preventing solar radiation from reaching the skin, and also in slowing down the conduction of heat from the environment to the animal. On the same grounds, clothing for man is an advantage in strong sunshine by preventing the absorption of radiant energy by the skin, and thus conserving water. But the fur must be sufficiently well ventilated to allow evaporation of sweat to occur at the base of the hairs so that heat may be drawn from the animal itself. If the fur is so thick that sweat travels through the layer in liquid form, evaporation occurs at the outer surface, heat is withdrawn from the air and the animal does not benefit.

We may compare the camel's performance with that of a man and a dog. Both these animals begin to evaporate water as soon as the body temperature rises above normal; man from the skin, and the dog from the respiratory surfaces. In this respect they are at a disadvantage as compared with the camel, which as we have seen allows its body temperature to rise.

In man, sweating increases with increasing heat load, and may reach 1.5 liters an hour. It continues at this high rate in spite of progressive desiccation. Renal loss decreases until the maximum urine concentration is reached, but this still involves about 0.5 liter of water a day. Maximum urine concentration in man is not very high, but even a doubling of the permissible concentration would not be very effective in desert conditions, for up to 50 times as much water is lost by sweating, and a saving of 250 ml. would be insignificant.

When supplied with water, however, man's capacity for physical work in deserts is better than that of the dog. This was made evident in an experiment (Dill, Bock, and Edwards, 1933) where a man and a dog walked a course in a desert when the air temperature was about 40° C. (104° F.). The man made five rounds, covering 20 miles, while the dog was completely exhausted after 16 miles. The man's skin temperature remained at about 34° C., but that of the dog rose, as a result of isolation, to about 45° C. After each round of 4 miles, both were offered water. The dog drank sufficient to restore its original body weight, but the man drank proportionally less and lost 3 kg. out of 75 kg. in 7 hours, which is equivalent to 4.2 percent of his body weight. There is an interesting reason for this. The sweat of man, although less concentrated than blood serum, con-

tains salt, and he drank only enough water to restore the normal blood salt concentration. The dog transpires from the lungs and thus loses no salt, so that it was able, by drinking, to restore all the water lost without lowering its blood-salt concentration. Dogs have the advantage of men in this respect.

Total evaporation from the dog was 2.6 percent of body weight per hour, that from the man was 1.74 percent; but if measured in terms of surface area, evaporation from the dog was lower: namely, 0.65 l./hr./m.² against 0.72 l./hr./m.² from the man. Since the body temperature of both remained constant, the difference in evaporation per unit area should reflect a difference in heat load. Heat is gained by metabolism, radiation, and conduction from the air. Metabolism is proportional to surface area in both animals and therefore adds an equal load to each; the radiation load, however, is lower in the dog because its skin temperature is higher. Thus when the surface temperature of the environment is 65° C. and a dog's skin temperature is 45° C., the gradient is 20° C. In man, with a skin temperature of 35° C., the gradient is steeper.

Again, heat flow by conduction to the air is outward in the dog (45° C. skin temperature and 40° C. air temperature), whereas in man heat flow is in the reverse direction. In this situation the dog, by not sweating from the skin and therefore having a higher skin temperature, had an advantage over man as far as water economy is concerned. However, long-term advantages in water conservation do not necessarily correspond with conditions of immediate comfort. A skin temperature of 45° C. in man would not be tolerable for long.

Strictly comparable figures for camels are not available, but the overriding fact is that a camel can tolerate a loss of water up to nearly 25 percent of its body weight while a man succumbs after losing 10 to 12 percent.

Summarizing the above, we see that camels, men, dogs, and kangaroo rats, all of them mammals, conform to expectations. The small ones avoid extreme conditions, and the large ones resist them by sweating. In addition, special adaptations, by modification of the general mammalian physiological plan, are apparent in typical desert inhabitants.

ARTHROPODS

We may now examine the situation in desert arthropods. Here we have to do with a rather different physiological pattern. All these animals are so small that active regulation of body temperature by evaporation of water is impossible, at any rate for more than very short periods, and water conservation is all important. They are all poikilotherms, and their temperatures fluctuate with that of the environment, so that toleration of a wide range of body tempera-

ture is the most efficient adaptation that they can possess. Nevertheless the ability to prevent undue rise in temperature for a limited period would be a distinct advantage in certain critical situations, and there is evidence that this does occur.

There are plenty of desert-living arthropods, including insects, spiders, and their allies, and even a few crustaceans. Rather less is known about the physiology of desert arthropods than desert mammals. What information exists, suggests that there are no striking physiological adaptations (Cloudsley-Thompson, unpublished), but this may be a mistaken impression because nobody has looked very carefully. Desert beetles have a rather less permeable integument than those from temperature climates, and the same is true of wood lice. On the whole, however, arthropods exist by avoiding extreme conditions. Because of their small size and mobility they are able to do so very well.

This focuses attention on an aspect of the problem which we have not so far considered in detail: the microclimates available for escape. There is by now a considerable amount of information on this subject, and I should like to consider two examples. Many years ago Williams investigated the variation in climate in a small area of the Egyptian desert. His conclusions, recently summarized (Williams, 1954), show how an animal, by moving through a very short distance, can avoid extremes of temperature and dryness. When the ground surface temperature was 56° C., 10 cm. below the surface it was only 34° C., and by moving up and down through a distance of 30 cm. in the soil, an animal could live in a constant temperature throughout the daily cycle.

A second example provides a rather interesting comment on Williams's work. It concerns some observations (Edney, 1958) on a desert woodlouse, *Hemilepistus reaumuri*. It is strange enough to find land crustaceans at all in desert conditions, and this species seems, so far as we know, to differ but slightly in physiological matters from its temperate relatives. It is larger than most woodlice, it runs with its body held well above the ground by longish legs, thereby avoiding contact with the hot surface, and its cuticle is less permeable to water than that of other woodlice. But it still breathes by what are essentially gills, and survives by digging small vertical holes about 30 cm. deep in which it spends the hot part of the day. Temperatures and humidities measured in the habitat of these animals show the efficacy of the retreat holes (fig. 2). These measurements also show that *Hemilepistus* transpires rapidly enough to reduce its body temperature significantly for short periods—a fact of considerable practical importance, for the animals emerge from their holes if the sun is covered by a cloud. As soon as the cloud

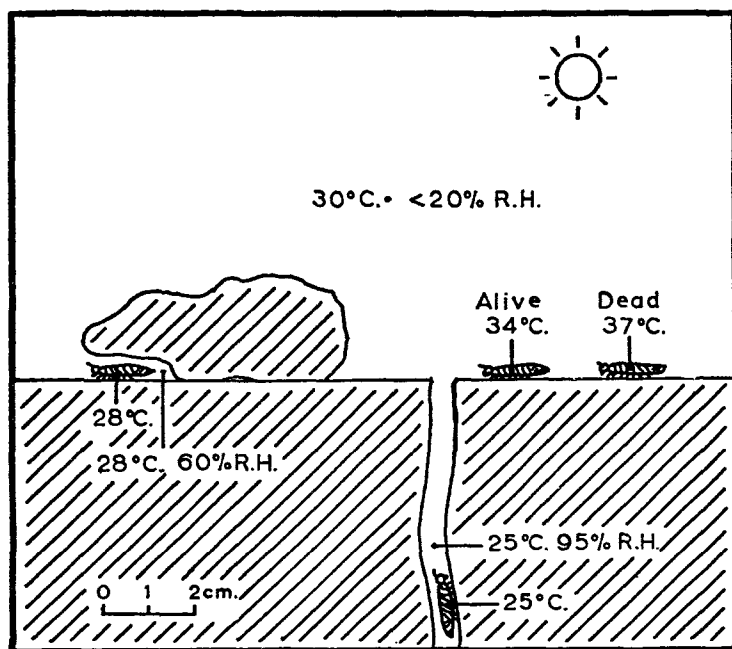


FIGURE 2.—A set of observations in the habitat of *Hemilepistus reaumuri* (Isopoda), in the Algerian desert.

passes, the surface of the soil and the air immediately above it undergo a very rapid rise in temperature (as much as 15°C . in 10 seconds). In such crises, ability to transpire rapidly while seeking shelter is undoubtedly an advantage to the animal.

It seems, then, that the physiology of arthropods in deserts, so far as it is known, conforms to expectation. They are too small to maintain a constant temperature by transpiration for long, and consequently they exist by avoiding true desert conditions.

Ability to transpire rapidly is certainly of some immediate advantage both for temperature depression and for respiration. But in the long run, it is a great disadvantage to small animals, for it restricts them to cryptozoic niches—moist, cool crevices which form only a small part of the terrestrial habitat. The most landworthy arthropods, not only in deserts but on land in general, have impermeable cuticles.

It may be permissible to speculate as to why woodlice, after living on land for at least 60 million years, have shown so little progress. Since some of the animals are still littoral, and their closest relatives are marine, there is strong evidence that the group migrated to land across the littoral zone. This is perhaps a more difficult route than that through estuaries and swamps because the problems of land locomotion, air breathing, and great temperature fluctuations are

presented all at once, rather than one at a time as they are along the other route. Now the littoral habitat is particularly subject to violent change, and a high transpiration rate would be of value both in permitting oxygen uptake in dry air through the integument, and in enabling the animals to reach shelter if they were caught in the open by intense solar radiation. This may be an instance of a group of animals having been caught in an evolutionary cul-de-sac, because the immediate survival value of a highly permeable cuticle prevented the development of those characters essential to land life. At least it can be said with confidence that until the twin problems of an efficient internal respiratory system and a greater temperature tolerance have been solved, the integument cannot be made impermeable and the animals will be prevented from full exploitation of the terrestrial habitat.

CONCLUSIONS

Let us now try to see desert animals as part of the general picture of evolution. It is sometimes said, or implied, that the terrestrial habitat is advantageous in the sense of encouraging biological progress. Are we then to think of desert animals, living as they do in extreme terrestrial conditions, as being the most progressive of animals?

Such statements are, of course, meaningful only if the term "progress" has been defined. The measurement of progress involves a criterion of perfection. It is legitimate and to some extent helpful to set up such a criterion, provided we realize that the choice is arbitrary. Thus we may measure progress, with reasonable objectivity, in terms of the range of habitats in which an animal can exist, or, and I think preferably, as Herrick (1946) and following him Simpson (1950) would have it, in terms of the range and variety of adjustments of the organism to its environment—that is, the degree of awareness of the environment and of ability to act accordingly.

If we may accept this measure of progress for the sake of the present discussion, the advantages of land life are plain. There is a greater variety of habitats on land. Temperature and humidity change more rapidly over a greater range and this calls for more complex behavior patterns to avoid extremes, or for internal homeostatic mechanisms to mitigate their effects. Again, the richer oxygen supply and rarer medium permit more rapid and sustained locomotion, which in turn calls for more acute sense organs—particularly for perception at a distance—and more complex behavior patterns to cope with the rapid tempo of life. I suspect that the development of homeothermy, which is itself a prerequisite for the development of intelligence, could never have occurred in aquatic animals because

of the high thermal capacity of water, the scarcity of oxygen, and the narrow range and slow rate of temperature changes.

These then are the possibilities offered by life on land: to be eligible for progress along these lines an animal must be terrestrial. But this is not to say that it must live in a desert, and we must look elsewhere for the reasons why some animals do so.

There is room, biologically speaking, for amoebae and for men; there is room for tapeworms, and shrimps, and land crabs. There is doubtless room for hosts of animals which have never been evolved. But life continues to exist at all levels of organization and in all biological niches once occupied while there is a possibility of existing there. There is no compulsion on all organisms to evolve into higher organisms. Progress is not inevitable. In other words, organic life flows into possible biological niches in all directions; it does not move steadily toward one goal.

The desert is one of these niches. Probably it is one of the most difficult of land habitats, but it would be a mistake to draw the conclusion that animals which live there are necessarily more advanced than others, in the sense of being able to live in a wider range of environments. Camels are clearly not more advanced animals than men on our agreed scale of progress. It is broadly true that life has evolved from "easier" to "harder" environments, and indeed a desert is one of the hardest. The animals which live there are well adapted, and their adaptations are interesting to explore. But many of them, particularly the arthropods, cannot live in moist cool surroundings. If versatility is a measure of progress, then desert animals have sold their inheritance for the immediate advantages of specialization.

As regards adaptation to terrestrial conditions as a whole, mammals and arthropods are the two most successful groups, but each group has its own secret of success. The mammalian plan is a good one: it allows a great variety of habitats to be occupied by a small number of relatively generalized species. Mammals can solve water and temperature problems in a generally applicable way, because they are large and can develop homeothermy. Arthropods, on the other hand, cannot solve all their water and temperature problems in a general way. They are too small, and they must solve some of their problems by specializing. Thus one species is specialized to tolerate a high range of body temperature, another a low range; one species can withstand dry air, another only moist air. Adaptability in arthropods is a property of the group as a whole rather than of individual species.

And now before I conclude, I must try to answer the inevitable question: what is the use of all this work on the physiology of little-

known animals living in little-known places? I do not believe this question to be irrelevant, for I am not one of those who maintain the sanctity of ivory towers, either scientific or otherwise. On the other hand, let us not make the error of thinking that all knowledge which is not immediately applicable is valueless. The value of fundamental biological inquiry lies in the greater insight it gives us into the way organisms work; and better understanding of any process permits more effective control. If we wish to manipulate the balance of nature, we must first of all understand its principles. In particular, the value of work on survival in hot dry climates lies in its ultimate application to the utilization of those vast areas of the earth's surface which are at present uninhabitable by mankind. For those who require applicability as an end to their endeavors, that must be the answer.

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Amphibians, Pioneers of Terrestrial Breeding Habits¹

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ANY TEACHER of comparative vertebrate anatomy who is worth his salt does, I am sure, emphasize the anatomical adaptations necessary for the invasion of land by the vertebrates. This aspect of evolution has been thoroughly explored, and within the limits of the paleontological record and the philosophical insight of man has been rather adequately explained. Another facet of the development of life on land is that of the environmental conditions under which these adaptations arose. These, too, have been investigated, and there has been in recent years a flurry of papers (Orton, 1954; Ewer, 1955; Gunter, 1956; Inger, 1957; Romer, 1958) discussing the ecological aspects of adaptation to life on land, in one of which the present writer had a hand (Goin and Goin, 1956). There remains another adaptational aspect, however, which I think has been neglected, and that is the development of those reproductive devices necessary to life on land. True, most elementary texts state that the final break with the water was made possible through the development of the shelled reptilian egg in which the embryo is enclosed in a fluid-filled sac by a new membrane, the amnion. They usually do not pursue the subject further unless it be simply to imply that the shelled egg made necessary internal fertilization. In fact, it is difficult even to find a literature reference to the idea that it must have been the other way around—that is, that internal fertilization made possible the development of the shelled egg.

It is this subject of the adaptive aspects of life history among the first terrestrial vertebrates that I want to pursue here. Surely we must not assume that only a single evolutionary attempt was made to

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modify a life history from that of an aquatic organism to that of a terrestrial organism. In fact, variability in reproductive pattern seems to be characteristic of the lower vertebrates. Diversity of life history is certainly well exemplified in the fishes, for example. Thus, in the grunions (*Atherinidae*) the eggs are deposited in sand on the beaches. The eggs of the Brazilian *Copeina arnoldi* are laid in jelly-like masses just above the waterline and are splashed by the male every 15 or 20 minutes until they hatch after about 3 days. Male climbing perch (*Anabantidae*) make floating bubble nests in which the females deposit the eggs. Males of sea catfishes (*Ariidae*) and mojarras (*Cichlidae*) carry the eggs in their mouths until they hatch, and in the well-known pipefishes (*Syngnathidae*) the female deposits her eggs in a brood pouch on the abdomen of the male. Here they are fertilized, the eggs hatch, and the young undergo their development. Internal fertilization is practiced by the sharks and top minnows (*Poeciliidae*), and in these groups the young are usually "born alive."

In each of these, however, the modification has resulted solely in the protection of the eggs from the exigencies of development in open water, since the adult itself never becomes terrestrial. This is not true of the amphibians. Comparative anatomy teaches us that adults of many of the modern forms have developed terrestrial characteristics while their reproductive habits still link them to the water.

It is impossible for us to examine directly the breeding habits of those early amphibians that moved their way out on land and gave rise to the truly terrestrial vertebrates. However, even today, 275 million years later, the amphibians are still trying to alter the piscine life-history pattern of depositing large numbers of small-yolked eggs in open ponds, on the chance that some of the offspring will live through to maturity. A study of these attempts may give us some clues as to how the change to terrestrialism was made. An examination of life histories shows plainly that many amphibians today do not at all follow what is known as the "typical" life history. Because the study of the amphibians developed largely in the North Temperate Zone, and because the frogs of this zone usually spawn in open water, with the small-yolked eggs hatching out into tadpoles which swim around until they are ready to transform into froglets, we often get the feeling that this is *the* amphibian life history. We are apt to overlook the fact that most amphibians live in parts of the world where the study of amphibians and reptiles has been least pursued and that the "typical condition" as given in an elementary zoology text may really, in a sense, be atypical. It may not even have been the characteristic pattern of the Carboniferous amphibians. Noble (1931) pointed out that the most primitive amphibians living today,

the tropical, wormlike caecilians, lay large-yolked eggs on land, and suggested that this may also have been true of the earliest amphibians. More recently, Romer (1957), in discussing the adaptive advantages of the terrestrial egg, hypothesized that the terrestrial egg preceded the terrestrial adult.

Several other aspects of amphibian life history have recently been explored by various workers. Lutz (1947) summarized the trend toward direct development in frogs, and a year later (Lutz, 1948) again discussed developmental variation, this time with particular emphasis on the amount of yolk in the egg. Orton (1949, 1951) has particularly interested herself in the modifications in the larval stages as correlated with direct development in frogs. More recently Jameson (1955) produced an excellent summary of modifications in mating behavior of the anurans.

Let me now summarize briefly the life-history modifications shown by the various living families of amphibians.

Caeciliidae.—Among the caecilians, internal fertilization is the rule. In the male, the cloaca (the common chamber into which the digestive and reproductive tracts empty) can be everted and serves as a copulatory structure when the cloacas of the two sexes are brought together. We find both aquatic and terrestrial caecilians and their life histories reflect these differences. In *Ichthyophis*, a native of Ceylon, breeding takes place in spring. A burrow is prepared by the female in moist ground close to running water. She coils her body about the 20 or more relatively large-yolked eggs and guards them zealously during development, protecting them from predatory snakes and lizards. The eggs swell gradually until they are about double their original size. When ready to hatch, the embryo weighs approximately four times as much as did the original egg. External gills are present at first, but these are lost soon after hatching. The larvae, which are aquatic, metamorphose into burrowing, limbless adults that would drown if kept under water. The genus *Rhinatrema* of northern South America likewise has eggs that hatch out into aquatic larvae with external gills.

On the other hand, *Gymnophis* and *Geotrypetes* retain the eggs in the oviducts and give birth to young which are replicas of the adults. The wall of the oviduct is provided with compound oil glands and the larvae subsist by literally eating the tissue of the wall with its included oil droplets.

Hynobiidae.—The hynobiids, primitive salamanders of the Old World, practice external fertilization, and the females deposit the eggs in egg cases. *Batrachuperus karlschmidti*, a common salamander of the small mountain streams of western China, attaches its egg cases in the stream bed proper, under or on the sides of large stones

in flowing water. These cases are mostly found in small brooks, especially near their source, where spring water seeps out of the ground or from under stones. The end of the egg case that is attached to the stone is flat and sticky and the body of the case is a cylindrical tube, larger in the middle and smaller toward the free end where it is smooth and transparent. The free end is covered with a smooth, cup-like cap which is even more delicate than the rest of the case. This cap is forced off by the movement of the fully developed embryos, and the young free themselves through the hole. The individual egg cases contain 7 to 12 eggs or developing embryos, and since as many as 45 eggs in the same stage of development have been taken from a single mature female, it follows that each female deposits 5 or 6 separate egg cases. The larvae are fairly typical salamander stream larvae.

Cryptobranchidae.—The salamanders of this family, like those in the family Hynobiidae, practice external fertilization. In *Cryptobranchus*, the hellbender of the eastern United States, mating takes place in the late summer. The male excavates a nest on the stream bottom beneath some large sheltering object, usually a flat rock, and will accept females that have not deposited their eggs. The eggs are laid in long rosarylike strings, one from each oviduct. These strings settle in a tangled mass on the bottom of the nest. As many as 450 eggs may be deposited by a single female, and several females may lay in a single nest. Fertilization is accomplished by the male discharging into the water a whitish, cloudy mass, consisting of seminal fluid and secretions of the cloacal glands, as the eggs are deposited by the female. After the eggs are deposited and fertilized, the male often lies among them with his head guarding the opening of the nest. It takes about 10 to 12 weeks for the eggs to hatch; the larvae transform at approximately 18 months.

Ambystomatidae.—In the family of the mole salamanders, two modifications not present in the previously mentioned families of salamanders show up: one is internal fertilization and the other is deposition of eggs on land. All the Ambystomatidae practice internal fertilization by means of spermatophores. These spermatophores are little packets of sperm, enclosed in a mushroom-shaped, gelatinous mass, which are deposited by the male and picked up by the cloacal lips of the female. Most of the ambystomatids, such as *Ambystoma tigrinum*, *A. maculatum*, and *A. jeffersonianum*, lay their eggs in water. In the last-named species, for example, the adults migrate to the breeding ponds in the early spring. The females usually outnumber the males and often must bid for attention during the mating season. After a characteristic courtship, the female picks up the spermatophore and deposits small eggs in cylindrical masses which

contain on the average about 16 eggs. These eggs are, of course, fertilized as they pass down the oviduct. Since the female may deposit over 200 eggs, it often takes a number of masses to complete a deposition. Typically, the incubation period ranges from 30 to 45 days, and transformation, or metamorphosis, follows 2 to 4 months after hatching.

A. opacum departs from this pattern to lay its eggs in the fall on land under old logs or other sheltering objects. The young, which hatch out on the advent of winter rains and make their way into the water, exhibit all the larval characteristics typical of other species of the genus.

Salamandridae.—The typical salamanders have developed a diversity of life-history patterns. Fertilization is internal by means of spermatophores. In the common American newt, *Diemictylus v. viridescens*, mating takes place in the spring. The eggs, numbering 200 to 375, are laid singly and usually are fastened to some aquatic object, such as a leaf or the stem of a small plant in quiet waters. Rarely they may be attached to the surface of a stone. The eggs hatch in about 20 to 35 days and the larval period usually lasts until fall.

On the other hand, some species of the Old World genus *Salamandra* exhibit modified life histories. *Salamandra atra*, for example, retains the eggs in the oviduct for the developmental period, and the young are born as fully metamorphosed individuals. In *S. salamandra* the developing individuals are retained in the oviduct for a time, but they may be born as late larvae, rather than as completely metamorphosed individuals. If the larvae of these two species are dissected from the oviduct, they are found to have the long filamentous gills and rudimentary balancers that are characteristic of pond larvae. This shows that in *Salamandra* the retention of the developing young in the oviducts is a modification of the aquatic form of life history.

Amphiumidae.—While details of the congo eel's life history remain to be discovered, the broad picture is evident. Fertilization is apparently internal and the eggs are laid in long, rosarylike strings in shallow depressions on land beneath old logs or boards. These strings contain, in some cases, at least 150 eggs. The normally aquatic female remains with the eggs and guards them during their developmental period.

Plethodontidae.—Members of this specialized family of salamanders also show some specialized life histories. Hence, not one but several accounts are needed to typify the breeding habits of this family. In all the species, fertilization is internal by means of spermatophores, but from this point on, there are modifications tend-

ing toward terrestrial adaptation. In the red salamanders, *Pseudotriton*, the eggs are deposited in small groups hanging from tiny rootlets and other submerged structures in cool, muddy springs. The female stays with the eggs, but apparently when they have hatched the larvae range for themselves. The dusky salamander, *Desmognathus fuscus*, on the other hand, lays its eggs not in the water but on land. They are deposited in small, grapelike clusters in shallow excavations in the soft earth, among bits of sphagnum, or underneath stones or logs. These excavations generally are within a few feet of the water. Upon hatching the young salamanders do not go at once to the water, but remain for a week or two on land and show definite terrestrial adaptations. The posterior limbs are longer in proportion to the trunk region than at any time during later development. Likewise the tail lacks a fin. In short, this young salamander is not merely a little larva which has not yet had a chance to reach the water but is basically a terrestrial salamander, able to move about in the damp crannies and crevices leading from the nest to the nearest pool or stream. After about 2 weeks these young terrestrial larvae take up an aquatic existence until such time as metamorphosis occurs, which it usually does when they are about 7 to 9 months of age. *Plethodon cinereus*, the red-backed salamander of the eastern United States, exemplifies the typical terrestrial plethodontid life history. The female lays 3 to 12 large unpigmented eggs in crannies and holes in rotten logs. Each egg adheres firmly to those previously laid, so that a little mass of eggs seemingly enclosed in a single envelope is formed. The egg cluster is usually attached to the roof of the cavity. The embryos develop rapidly and soon exhibit well-developed external gills. These, however, are lost on hatching. The young emerge in the same form as adults and never take up an aquatic larval existence. Finally, *Hydromantes* and *Oedipus* retain the eggs in the oviducts and give birth to fully transformed young.

Proteidae.—This family, which includes the well-known mud puppy, *Necturus*, is somewhat isolated structurally from the other salamanders and its members never completely metamorphose. Fertilization is internal. The female of *Necturus maculosus* lays eggs singly in still water and attaches them to the undersurface of rocks, boards, or other objects, usually in water 3 to 5 feet deep and from 50 to 100 feet from shore in shallow lakes, although they have been recorded from streams. There are from 18 to 180 eggs in each clutch. They hatch after 4 or 5 weeks. In this genus there is, of course, no metamorphosis, since these salamanders are aquatic and retain their gills throughout life. The European olm *Proteus*, under some conditions, does not lay its eggs but rather retains them in the oviduct where the young undergo development, finally to be born as salamanders, which are but miniature replicas of the adult. In contrast

to the caecilians, there are no special modifications known of either the larvae or the oviduct to permit this change in life history.

Sirenidae.—The aquatic sirens have been reported time and time again to exhibit external fertilization, but these reports have been based on the fact that no one has yet demonstrated either the production of spermatophores by the male or the presence of a receptacle for storing the sperm in the cloaca of the female. Nonetheless, I am not yet convinced that the Sirenidae practice external fertilization. In *Pseudobranchius*, the dwarf siren, the eggs are deposited singly on the roots of water hyacinths and are so widely scattered that often an entire afternoon's collecting will produce less than a dozen eggs. They may be spaced as much as 5 or 10 feet apart. Dissection of mature females readily demonstrates that they may have well over 100 eggs ready for deposition at one time. It seems inconceivable that such a large number of widely scattered eggs could be fertilized externally. The eggs hatch several weeks after deposition, but of course the young larvae never metamorphose because these, like *Necturus*, are aquatic forms that retain the gills. Since in both the Hynobiidae and the Cryptobranchidae, the two families of salamanders that are known to have external fertilization, the eggs are laid in clusters, either in little capsules or packages, or in rosarylike strings, it would seem that the habit of spacing the eggs at wide intervals would be unique among salamanders with external fertilization if the Sirenidae are, in fact, really salamanders—but that is another story.

Leiopelmidae.—These primitive frogs have internal fertilization with the "tail" (cloacal appendage) of the male acting as a copulatory structure. In the tailed frog, *Ascaphus*, the voiceless male swims about on the bottom of a flowing stream until he finds a female. He grabs her and secures a firm grip, clasping her just in front of her hind legs and humping his body so as to bring his extended cloacal appendage into position to thrust into her cloaca. The sperm is apparently transported to the female cloaca by means of this appendage. The eggs are deposited in coils of rosarylike strings which adhere to rocks at the bottom of the stream. In the cold water in which these eggs are deposited, embryonic development is slow, and transformation does not occur until the following summer. The only close relative of *Ascaphus* is *Leiopelma* of New Zealand. This frog has been reported to lay eggs on land which go through direct development, but the details of mating and method of egg deposition are unknown.

Pelobatidae.—As in other families, there is a good deal of variation of life histories in the burrowing toads. The reproductive pattern of the spadefoot toad, *Scaphiopus h. holbrooki*, is somewhat typical of the New World forms in that there is a speeding up of the developmental processes in correlation with the habit of breeding in temporary waters. In torrential rains and hurricanes any time of the

year from early spring to late fall, males emerge from their burrows and move to temporary rain-filled pools where they call vigorously. Calling takes place both by day and by night. When the females reach the ponds, they are clasped by the males and egg deposition occurs. The toads cling to a stiff spear of grass or other piece of vegetation beneath the surface of the water and slowly crawl up the stem, in a few minutes depositing a string of about 200 eggs. The tiny eggs hatch in a fairly short period of time, depending in part on water temperature and other external factors which have yet to be determined. Under certain conditions they may hatch within a day and a half. The little tadpoles remain in the pool for a varied period of time, depending again on conditions within the drying-up pool. That local environmental conditions have their effect can be easily demonstrated. My wife and I have taken tadpoles from a drying pool in our backyard and put them on the back porch in a jar of water from the pool, leaving other tadpoles in the puddle. Those tads left in the puddle emerged just prior to the drying up of the pond, while those in the jar of water on the back porch continued to exist for several weeks afterward as untransformed tadpoles.

On the other hand, in the Old World pelobatid *Sooglossus seychelensis* the eggs are laid on land and the tadpoles are carried about adhering to the male's back where they undergo their development. The eggs are fairly large and the larvae hatch with hind-leg rudiments present, but have neither external nor internal gills at any stage of development.

Pipidae.—Three types of life history are exemplified by the very aquatic frogs of the family Pipidae. In the Old World forms, such as the African clawed frog, *Xenopus*, the eggs are deposited in the water and are attached to weeds. On the other hand, in the five American species, including the Surinam toad, *Pipa pipa*, eggs are placed in pouches on the backs of the females. These pouches are temporary pits formed in the soft skin of the dorsum. Development is direct in two species and probably also in a third, but in the other two the eggs hatch into tadpoles that resemble those of the Old World species.

Discoglossidae.—The mating behavior of the obstetrical toad, *Alytes obstetricans*, has been worked out in rather careful detail. The males call from small holes in the ground. Mating occurs on the ground nearby and is apt to last most of the night. The male clasps the female tightly around the head above the forelimbs and gently massages her cloacal region with his toes. Just before the eggs are laid, the male moves his hind legs forward so that his heels are together anterior to and above the cloaca of the female. As the eggs are emitted the male catches the mass in his feet and, by stretching his legs backward, delivers from 20 to 60 eggs which the female expels

with a sudden noise. The male then moves his legs around, entwining the eggs about his legs. He carries them for several weeks, until the tadpoles are about ready to hatch, at which time he makes a brief visit to a pool where no other tadpoles are present. Here he deposits the eggs; the little tadpoles hatch out and finish their development as tads in the pool.

Bombina maxima, the yellow-bellied toad, breeds in the water. The male clasps the female just above the front of the hind limbs and the eggs are laid in small masses which, instead of being wrapped around the legs of the male, sink to the bottom or come to rest suspended on submerged vegetation. Here they lie until the eggs hatch.

Rhinophrynidae.—The Mexican burrowing toad, *Rhinophrynus*, exhibits an aquatic courtship, the males grasping the females in front of the hind legs. The eggs are then deposited in the water where they hatch out into aquatic larvae which later undergo metamorphosis.

Leptodactylidae.—The two abundant genera of New World leptodactylids, *Leptodactylus*, the nest-building frogs, and *Eleutherodactylus*, the robber frogs, have rather uniform life histories among themselves. The species of *Leptodactylus* build frothy nests in or near bodies of water. The eggs are deposited and hatch within these nests. The larvae have very slim bodies and make their way through the nest to the adjacent water. While there is some variation in larval form among the different species, in general throughout the genus there is agreement of nest form and larval habits. A few leptodactylids have become more terrestrial. *L. nanus* scoops out a small basin in the earth at a site some distance from the water. The froth and eggs are deposited in this basin which is then roofed over with mud. A tiny aperture is left at the top through which the young escape after metamorphosis.

Eleutherodactylus lays its eggs on land. Here, about sunrise in the morning, generally under stones or logs or similar cover, the female deposits her eggs while clasped by the male who fertilizes them as they are deposited. These eggs go through direct development and at hatching the little froglet is a miniature replica of the adult.

Life histories of *Paludicola* and *Eupemphix* are similar in pattern to that characteristic of *Leptodactylus*. *Zachaenus*, like *L. nanus*, lays its eggs in an earth basin, but the basin is not roofed over. The young, however, complete metamorphosis in the basin as do the young of *L. nanus*.

In the Australian *Heleioporus eyrei*, the eggs are laid in a frothy mass of jelly underground in the spring of the year. Development proceeds within the egg until the external gills have been lost and the gill covering developed. Hatching seems to depend on the nest being flooded.

The Australian *Limnodynastes tasmaniensis* lays small eggs which are enclosed in a gelatinous frothy mass floating on any available water supply. These eggs hatch in about 48 hours and the newly emerged larvae make their way from the frothy mass into the water where they immediately attach themselves to water plants, debris, or other submerged objects.

Centrolenidae.—Not too much is known concerning the breeding habits of this distinctive little family of tree frogs. The eggs are deposited in disklike masses on the undersides of green leaves. These masses are invariably above running water, into which the tadpoles fall on hatching. It has been reported for *Cochranella fleischmanni*, of Barro Colorado Island, Panama Canal Zone, that the easiest way to locate the frogs is to search out the egg masses. At night a male will nearly always be in attendance. Multiple matings by a single male have been reported for this species.

Bufo.—The true toads, like so many other anuran families, show a diversity of life histories. In the genus *Bufo* the males go to the ponds in spring, in the Northern Hemisphere at least, and give their calls. When the female approaches the male, the latter embraces her behind the front legs and the pair float at the surface, the male leaving his hind legs hanging free. As the female deposits the eggs, the male brings his knees to rest in her groin with heels almost touching. The female pushes along the bottom and deposits strings of small-yolked eggs, which may number in the thousands. They hatch in 2 to 4 days into little, short, polliwog-type tadpoles. These tadpoles transform into tiny toads a month or two later.

In the African genus *Nectophrynoides*, which contains but three species, the eggs are not laid but are retained in the body of the female where they hatch; the young go through their larval development in the oviducts of the mother. The number of young is greatly reduced in comparison to the number produced by the toads that lay their eggs in water, but even so, more than 100 may be taken from a single female of *Nectophrynoides vivipara*. Despite the fact that these larvae remain in the oviduct rather than having a free-living tadpole stage, few of the important characters of tadpoles have actually been lost. Transformation takes place within the oviduct and fully developed young are born. No copulatory organs have been described for this genus of frogs, and how the spermatazoa are transmitted from the male to the female is not known.

Rhinodermatidae.—The small Andean Darwin's frog, *Rhinoderma darwini*, has one of the most unusual of all life histories known among the frogs. Several males will watch a clutch of 20 to 30 eggs, deposited on land by a single female, for 10 to 20 days, until they are nearly ready to hatch and the embryos can be seen moving inside them. Over a period of several days, each male then picks up

a number of eggs, one at a time, with his tongue and slides them down into his vocal pouch. Here the young pass the larval stage. They do not emerge until metamorphosis is completed. Although it lacks a free-living larval period, the developing frog is for a time completely tadpolelike.

The tiny *Smynthillus limbatus* of Cuba lays one large-yolked egg on land which hatches into a fully formed frog.

Dendrobatidae.—The little poison frogs are apparently rather uniform in the fact that the male carries the tadpoles on his back until he deposits them in a body of quiet, casual water. In *Dendrobates auratus*, the male has no definite calling site but makes a low buzzing sound as he moves about over the ground on a morning after a rain. Usually a male will be followed by several females, some of which will actually jump on him. He is apparently aware of his admirers because if pursuit lags, he slows down and becomes more vociferous. Finally he dives beneath the wet leaf mold and is followed by a female. The details of mating are not known and in fact it is not even sure that it does take place under these situations. It is known, however, that the female lays on land from one to six rather large-yolked eggs which are surrounded by an irregular, sticky, gelatinous material with no definite external film. These eggs hatch in about 2 weeks. The male either guards or visits the clutch, and the newly hatched tadpoles wriggle onto his back. Some time later he moves to the water and the tadpoles slide off. Tadpole-carrying males have been noted in trees quite some distance from water, although it may be that they were carrying tadpoles up to tree holes which contained water. Tadpoles collected in water have been known to live for at least 42 days before transformation. Similar habits are shown by the related genera, *Phylllobates* and *Prostherapis*, although apparently the number of tadpoles carried by an individual male is greater. In *Phylllobates*, males have been found carrying as many as 15 tadpoles, and tadpole-carrying males of this genus have been seen as far as a quarter of a mile from water. A specimen of *Prostherapis fuliginosus* has been taken with 25 tadpoles on the back.

Atelopodidae.—As far as I know, the brightly colored little toads of this family exhibit aquatic breeding habits with indirect development—that is, the eggs are laid in water and pass through a tadpole stage before transformation.

Hylidae.—The tree frogs have very diverse life histories. One group comprises a few genera of South American frogs placed together in the subfamily Hemiphractinae. These include *Cryptobatrachus*, *Hemiphractus*, *Gastrotheca*, and *Amphignathodon*. While typically hylid in appearance, these frogs have the habit of carrying eggs in a mass on the back of the female. In some, this mass is imbedded in or covered by a fold of skin which forms a veritable sac as

in the marsupial frog *Gastrotheca marsupiata*. In others, such as *Cryptobatrachus evansi*, the female carries the eggs exposed on the back where they go through their development. In other hylids assigned to the subfamily Hyalinae, the life history is less modified, but even here there are specializations. In the Central and South American genus *Phyllomedusa*, for example, the male clasps the female while she moves about through the trees and selects a leaf over water on which to deposit her eggs. While spawning, the pair move slowly forward from the tip of the leaf toward the stalk, folding the leaf into a nest and filling it with eggs and foam. The two ends of the leaf are left open. In this foamy mass the eggs develop into tadpoles which then fall through the hole in the end of the leaf into the water below. In *Hyla decipiens* likewise the eggs are laid in a gelatinous mass on a leaf overhanging sluggish water. Upon hatching, the larvae break free and fall into the water.

Hyla rosenbergi and *Hyla faber* build basins of mud on or near the edge of pools. In these basins they deposit their eggs. The tadpoles have enormous gills with which they adhere to the surface film of these basins. With the rise of water following the rains, the tadpoles make their way into the body of the pool or stream.

In *Hyla goeldi* the eggs are carried on the back of the female until ready to hatch, at which time the mother goes and sits in the water while hatching progresses.

In Jamaica, all the species of *Hyla* have specialized breeding habits. They deposit their eggs in the little water held at the base of the leaves of "wild pines" or bromeliads. Here the little tadpoles hatch out and start through their development. Food is quite scarce in this environment and the tadpoles have become specialized for feeding upon the eggs laid either by the mother or some other female. In some forms, at least, they may eat the eggs of other species, but certainly in *Hyla brunnea* it can be demonstrated that they eat the eggs of their own species, for in certain parts of the Blue Mountains where I have observed this behavior, *brunnea* is the only *Hyla* present. Not only do the tadpoles eat the eggs of their own species, but, in all probability, they eat the tadpoles of the same clutch. As one watches a developing nest, in the early stages there are many tadpoles present, but as time goes on the tadpoles become fewer and fewer, so that by the time transformation is about to take place perhaps less than half a dozen living tadpoles are left to transform. The reduction in teeth and the extremely long tails of these tadpoles are presumably modifications for existence in this environment. Similar egg-eating tadpoles have been described for a continental genus of hylid, *Anotheca*, of Mexico and Central America.

Many of the hylas do, however, have the habit of breeding in open water with the unprotected eggs transforming through the tadpole

stage into little frogs. In the gray treefrog, *Hyla versicolor*, for example, the adults go to the ponds from April to early summer to breed. The eggs are laid, scattered in small masses or packets of not more than 20 to 40 eggs each, on the surface of quiet pools. These packets are loosely attached to the vegetation. The egg itself is but slightly larger than a millimeter in diameter while the outer envelopes may be more than 4 mm. in diameter. The eggs hatch in 4 to 5 days and the tadpoles emerge to swim around and feed in the pond for about a month and a half to 2 months until they transform, usually in the middle or late summer, into small frogs that may be from 15 to 20 mm. in snout-to-vent length.

Ranidae.—The typical life-history pattern of the so-called "true frogs" of the genus *Rana* is too well known to deserve more than passing mention. In *Rana pipiens*, the leopard frog, the eggs are laid in the spring months. They are deposited in large masses attached to submerged plants, twigs, or sticks, or they may even rest on the bottom, unattached, in open ponds and marshes. After hatching, the tadpole exists as a sunfish-type tadpole with a very high tail fin for 2 or 3 months. The tadpole itself is quite large and often exceeds 3 inches in length.

A couple of Oriental species of *Rana* lay their eggs out of water on leaves or stones or even in the mud near the bank, but these egg masses are essentially unmodified and the larvae which escape from them soon make their way into the water. This habit of laying its eggs out of water is also found in the South African genus *Phrynobatrachus*. All the species of *Staurois*, a genus characteristic of mountain-torrent regions of southeastern Asia, lay their eggs in the pools below the cascades. These eggs hatch out into aquatic tadpoles that are especially adapted for life in mountain torrents by having large suctorial disks back of the mouth.

In the genus *Cornufer* of the East Indies we find the extreme modification in ranid development in that, instead of hatching out into tadpoles which later metamorphose, development is carried on in the eggs which are laid on land and which hatch out directly into fully formed tiny froglets.

Rhacophoridae.—The Old World tree frogs typically lay their eggs in masses of foam on the leaves of plants or other structures above the water. The habits of *Rhacophorus leucomystax* may be taken as an example. The breeding season is apparently very long, egg foam having been collected from late April through August. The breeding places include the walls of unused manure pools and sometimes the crops in flooded fields. If no suitable pool or other water is available, the egg foam may be laid on the ground during rainy evenings. During the process of egg laying, the female does most of the work

of producing the foam mass. Before the eggs appear she ejects a small amount of fluid, and this she beats into a froth by moving her feet medially and laterally and turning them as she crosses them on the midline. When the foam for holding the eggs has been prepared, the eggs and the fluid come out together. During the egg-laying process, the male is passive, grasping the female under the armpits and simply holding his body closely applied to her back, his eyes half closed. His pelvic region is bent down with the cloacal opening near that of the female. Apparently the eggs are fertilized as they leave the cloaca of the female. When the egg-laying process has been completed, the female stands up on her forelimbs and the male tries to get away from the foam in which the distal ends of his hind legs are buried. The female usually gets away from the foam later by moving her legs and body sideways with the help of large sticky finger disks. The foam is white at first but in a few moments changes to light brown. The eggs, which are without pigmentation, are scattered singly or in small groups in the big foam mass but are mostly concentrated near the basal part where the foam is attached to the substrate. The incubation period apparently varies with the temperature, and in some cases has been known to take from 6 to 7 days. The tadpoles also hatch in different stages of development. Some of the newly hatched individuals have external gills fully exposed while others have their external gills partly covered by the operculum and are much more heavily pigmented. Near the time of hatching, the foam containing the embryos begins to liquefy and the active movement of the fully developed embryos or tadpoles in the liquefied foam drops them into the water below. Sometimes the whole egg foam mass with its contained tadpoles may be washed down by rain into the pool below. When the liquefied foam drops into the water the tiny bubbles in it disappear and the tadpoles swim actively in the water. A few rhacophorids lack the habit of "egg beating." For example, African frogs of the genus *Hyperolius* lay their eggs in small clusters directly in the water. *Kassina* is apparently quite closely related to *Hyperolius*, and it likewise lacks the habit of "egg beating." Its eggs are small and pigmented and laid singly or in pairs in the water.

Microhylidae.—In the narrow-mouthed toad, *Microhyla carolinensis*, the eggs are pigmented, firm, and rather distinctively shaped. The complement ranges from 700 to 1,000 eggs which float at the surface film. The tiny tadpoles lack teeth on the mandibles. They metamorphose, in a period ranging from as little as 20 to as much as 70 days, into tiny frogs. This sort of life history is fairly typical of most microhylids but not of all of them. Some species lack the prolonged free-swimming tadpole stage; either the egg hatches as an advanced-staged tadpole or metamorphosis is completed within

the egg and a tiny froglet hatches out. This is so, for example, with *Breviceps pentheri*, of British West Africa. In this species the eggs are laid in holes on land and there is no free larval stage at all; the developing embryo lacks many of the typical tadpole structures. The tail is quite large and is presumably used as a respiratory structure, as it is in the genus *Eleutherodactylus*. The extreme microhylid life history is shown by the genus *Hoplophryne* of East Africa. *Hoplophryne uluguruensis* lays its eggs between the leaves of wild bananas or within the nodes of the stems of bamboos which have been split sufficiently to permit the entrance of this small and exceedingly depressed frog. Small amounts of water are retained in the leaves of wild bananas, but its presence has not been determined for the internodal chambers of the bamboos. The eggs hatch into tadpoles which have become specialized, as is the case in certain hylids, for existence in these rather barren environments. They have apparently taken up the habit of eating frog eggs, perhaps of their own species, and the tadpoles are consequently modified. Superficially these modifications remind one of those found, for example, in *Hyla brunnea*. The teeth are reduced to the point of being entirely absent, and the tail, like that of *Hyla brunnea*, is long, slender, and whiplike. These modifications are, of course, apparently secondary and in no sense imply close relationship.

Phrynomeridae.—Apparently the African toads deposit their eggs in open water. The eggs hatch out into tadpoles which later metamorphose much as do most microhylids.

DISCUSSION

To be somewhat anthropomorphic, it is evident that the amphibians are still, today, striving toward elimination of the open-water habitat for their eggs and early larvae, as were the primitive forms that gave rise to the higher vertebrates, in which the amnion is always present. This leads, of course, to the basic problem of what were the life-history modifications that made possible the development of the amniotes.

As can be seen from the foregoing survey, the problems arising from the deposition of eggs in open water may be avoided in part or in whole in several ways. There may be an acceleration of development so that the eggs and larvae are not left for so long a period of time subject to the catastrophies that may befall them in open water. Then, also, there is the retention of the eggs in the body of the mother. This, of course, is possible only when preceded by internal fertilization. The latter, though, has developed at least three times without leading to the amniote egg, for the modern caecilians, most of the salamanders, and some of the frogs today practice this form of fertilization. Then there can be parental care, where the parent, instead

of abandoning the eggs, takes them with him, or her, as the case may be, and cares for them until development is advanced or even until transformation is complete. Furthermore, the deposition of the eggs in out-of-the-way places has been a successful device for getting the eggs away from open water. They may be deposited on land, in trees, or in little secluded bodies of water where they are more or less isolated, as in the bromeliad-breeding frogs. Correlated with these egg-protecting mechanisms, there may be direct development in which the larval stage is omitted. Since the larva of an amphibian is essentially an aquatic form, terrestrial breeding habits eliminate the need for this stage in the life history.

The following analysis, patterned after that of Gadow (1909), lists the major types of amphibian life histories and the families that have at least some representatives exhibiting such modifications.

- I. Eggs small, the larvae hatching in a comparatively early state of development.
 - A. Eggs laid in water.
 1. Eggs laid in open ponds and streams: some representatives in all the families of salamanders except the Amphiumidae and the Plethodontidae and in all the families of anurans except the Centrolenidae, Dendrobatidae, and Rhinodermatidae.
 2. Eggs laid in underwater crevices and crannies (Plethodontidae); in specially walled-off parts of the pond (Hylidae); in basins of water collected in bromeliads, bananas, bamboo, etc. (Hylidae and Microhylidae); or in foamy masses (Leptodactylidae).
 - B. Eggs deposited out of water.
 1. In holes, under logs, rocks, or debris, from which the larvae must make their way to the water, sometimes aided by heavy rains: Ambystomatidae, Amphiumidae, Plethodontidae, Leptodactylidae, Ranidae, and Rhacophoridae.
 2. On leaves (or sphagnum) above the water. The larvae on hatching, drop into the water below: Plethodontidae, Centrolenidae, Hylidae, and Rhacophoridae.
- II. Eggs relatively large and the young at least initiating metamorphosis while in the egg.
 - A. Eggs deposited in damp situations and perhaps guarded but never carried about by either parent.
 1. The young hatching as larvae: Caeciliidae, Plethodontidae, Leptodactylidae, Hylidae, Ranidae, Rhacophoridae, and Microhylidae.
 2. The young hatching as miniature replicas of the adults: Leptodactylidae, Leiopelmatidae, Rhinodermatidae, Ranidae, Phacophoridae, and Microhylidae.
 - B. Eggs and/or larvae carried about by a parent.
 1. By the male.
 - a. Wrapped around the legs: Discoglossidae.
 - b. In the vocal sacs: Rhinodermatidae.
 - c. On the back: Pelobatidae, Dendrobatidae, Ranidae.
 2. By the female.
 - a. Buried in the skin of the back: Pipidae.
 - b. In a pouch or free on the back: Hylidae.

- III. Eggs retained in the oviduct of the female and the young "born alive":
Caeciliidae, Proteidae, Salamandridae, Plethodontidae, and Bufonidae.

Perhaps the most obvious thing that can be ascertained by a study of the above outline is the fact that there is so little correlation between the life histories of the amphibians and their evolutionary relationship. Here we find a form of copulation in the caecilians and frogs, and internal fertilization without copulation particularly common in the salamanders. We find both small eggs with indirect development (with an intermediate, free-living larval stage), and large eggs with direct development, in the salamanders and in the frogs and toads. It has been shown by Moore (1942) that in certain groups of frogs there is a tendency to have larger eggs toward the Temperate Zones and smaller eggs toward the Tropics but even here there are exceptions (Moore, 1949), for *Rana pipiens*, the leopard frog, lays larger eggs in Mexico than it does in the northern United States. But this does not explain the tendency toward large eggs and direct development in the leptodactylids, hylids, and rhacophorids, all of which are essentially tropical groups.

It appears then that there is nothing about the diverse life histories of modern amphibians to give a sure clue to the development of the land egg. Since this is so, perhaps we had best look at reptilian reproductive habits and see if it is possible to figure out the combination of factors that made possible the reptile pattern of reproduction.

CHARACTERS OF REPTILIAN REPRODUCTION

1. Internal fertilization. This is necessary because the sperm must enter the egg before the shell is deposited around it by the glands of the oviduct.
2. Copulation, an effective and apparently efficient method of achieving internal fertilization.
3. Eggs laid on land in a protected spot. (Sometimes the young are "born alive," but this is certainly secondary in the reptiles.)
4. Egg with yolk mass large enough to carry the embryo through development, until the adult body form is reached.
5. Development direct without an intermediate larval stage.
6. Egg cleidoic, that is, with a fluid-filled amnion and protective shell.

From a consideration of this list, we can trace a probable course for the evolution of breeding habits in the amphibian stock leading to the reptiles. The first step away from the primitive pattern of laying a large number of unprotected eggs in open water was probably to lay the eggs in a sheltered spot away from the main body of the pond or stream. Next would come deposition of the eggs in a humid, protected spot on land, depending on some mechanism (heavy rains, flooding, falling from overhanging leaf, or transportation by parent) to release and return the newly hatched larvae to the water. Once this stage was reached, an increase in yolk supply in the egg would be advantageous since it would allow the embryo

to continue development when the releasing mechanism was delayed. With the protection of the eggs, the need for enormous numbers would be lessened, and the female could concentrate on producing a fewer number of large-yolked eggs. A continuation of the trend toward the prolongation of development within the egg would lead eventually to metamorphosis before hatching. With the elimination of the free-living larval period, the typical larval characters would tend to drop out, resulting in direct development. All these stages are represented in the life histories of modern amphibians. They are thus, we can be sure, all practicable ways for an amphibian to reproduce its kind. Furthermore, each step would seem to have a selective advantage over the one before.

Somewhere along the line, these amphibian ancestors of the reptiles must have adopted the practice of internal fertilization with copulation. This, too, is found in modern amphibians and would seem to be advantageous for animals breeding on land.

The stage would now be set for the development of the typical reptilian cleidoic egg with its fluid-filled amnion and protective shell. It is hard to visualize these structures evolving in an aquatic egg, but in one that was already terrestrial, anything that reduced the dependence of the developing embryo on environmental moisture would be decidedly advantageous.

It is impossible to determine, of course, how these changes were correlated with the anatomical changes by which the amphibian body plan turned into the reptilian body plan, or even to know where we should draw the line separating the two orders. In the present state of our knowledge, it is at least permissible to hypothesize that by about the time the shelled amniote egg had developed, the animal that hatched from it had progressed far enough to be called a reptile, and this seems as good a place as any to draw the line. It has the advantage of being a line that separates the modern forms as well. It seems probable, though, that we should revise our conception of the significance of the cleidoic egg. Perhaps it was not the first reptiles that broke the bond yoking the vertebrates to the immediate vicinity of water for reproduction. It seems more likely that these reptiles descended from amphibians that were already fully terrestrial in their breeding habits, that practiced internal fertilization by copulation, and laid large-yolked eggs in sheltered spots on land, from which the young developed directly with no intermediate aquatic larval stage.

As for the other amphibians, it is obvious that many of them have acquired independently one or more of the reptilian breeding characteristics listed above, but presumably not since the days when their ancestors paddled about in the Paleozoic puddles has any amphibian acquired them all and thus developed into an amniote. The rest of

the amphibians are either, evolutionarily speaking, still trying this method or that to avoid leaving their eggs in open water, or else, since reproduction in water seems inevitable, have, as a Chinese philosopher might have advised, learned to relax and enjoy it.

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A Study of the Biology of Saturniid Moths in the Canal Zone Biological Area

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[With 5 plates]

CURRENT evolutionary biology has seen a striking revival of interest in the theory of protective coloration. The essence of the several separate hypotheses of which the theory is composed is that all, or nearly all, animal coloration is meaningful in that it confers protective advantages upon the animals bearing it, and that the various categories of special adaptations, such as procrypsis, the mimicking of palatable forms by those which are distasteful, and the advertisement of distasteful forms by bright and contrasting color, have all been evolved in response to selection pressures mediated by predators. The earlier widespread interest in protective adaptations, which was largely fostered by Sir Edward Poulton and his school in Oxford at the end of the 19th century, did not survive in its full vigor to experience the discipline which 20th-century genetic analysis could have imposed upon its largely anecdotal framework. Instead, in the period between the wars, it withered under the critical fire of laboratory zoologists who were unable to accept the apparent gap between the abilities which protective adaptations seemed to demand of the predators against which they had supposedly been evolved, and the abilities which such animals were known, as scientific fact, to possess.

To a great extent, this skepticism followed from an experimental discipline of behavioral research which placed too much emphasis upon the simpler reflex and tropistic phenomena. Then, too, natural selection had replaced God in the problem of creation; and its creators, losing faith in their demon, were now unwilling to admit that it was a fine enough instrument to achieve those ends which were manifestly present in nature as *faits accomplis*. On the one hand, in the shape of butterflies perfectly resembling dead and moldy leaves, warningly striped and nauseous beetles, or moths equipped with giant owl-like eyes, they could see all the evidence for a sophistication of perceptual ability surely only to be found in man himself: on the

other, they were aware of a vertebrate world not sharing human abilities in lesser degree, but brutish in the pejorative sense; reflex; qualitatively different.

Our hunting fathers told the story
Of the sadness of the creatures
Pitied the limits and the lack
Set in their finished features . . .¹

The 20th-century biologist surveyed the white rat in its aseptic cage, solving with deplorable sloth problems barely related to any that it would be likely to encounter in its own unhygienic habitat, glanced with discomfort at the baroque elaboration of natural forms, and proposed, with a conviction which in the worst cases was soon to become hysterical, a series of wholly implausible alternative explanations. With these, we need not be concerned here; it is enough to note that they ranged from flat denial of the evidence, to assertions that coincidence alone needed to be invoked as a sufficient explanation of it.

The renaissance of protective-coloration theory has to a great extent followed the Second World War. The original accounts of tropical insects from which it was derived came from experienced field naturalists, such as Bates, Hudson, and Belt. And, again, its rediscovery came very largely from the European group of ethologists, also, basically, field naturalists, who were stimulated by accounts of experimental work on cryptic coloration started between the wars, and admirably summarized in a now classic work by the Cambridge zoologist H. B. Cott (1940).

The major problems with which they had to deal may be easily set forth: First of all, faith in the efficiency of selection pressures had to be restored. Secondly, the behavior of predators needed to be so analyzed as to reveal the manner in which the selection pressures created by them must operate. Lastly, the genetic material upon which selection must act and its potentiality for variation had to be related to the findings of the behavior studies. These various lines of approach and some of the findings have been described by Tinbergen (1958).

My own connection with these studies began in 1953, when, under the supervision of Dr. N. Tinbergen at Oxford, a program of work was started on the functions of the eyespot patterns of insects. The outcome of this research was a demonstration that the eyelike patterns on the wings of many butterflies do, in fact, serve to scare away avian predators, and that the selective advantages which they confer are of a high order (Blest, 1956, 1957a). At this stage in the investigation a further problem was presented; there are groups of insects some

¹ W. H. Auden, *Collected shorter poems*. London, 1950.

of whose members possess eyespot patterns, while their near relatives are either aposematically colored, or are equipped with procryptic patterns. Eyespots are characteristically concealed at rest, and exhibited in response to disturbance by sudden movements of the portions of the body either bearing them or concealing them. What, then, is the relation between the distinct modes of behavior that might be expected to be linked with the various types of coloration and from what evolutionary source have they been derived? Numerous studies have testified to the close association between signal movements and the morphological patterns that they display (Tinbergen, 1952; Blest, in press [B]); here was an ideal case for a comparative investigation. The most readily available group of insects was the tropical Saturniidae, or "Emperor moths," living pupae of which are freely available in the commercial market where they satisfy the demands of amateur lepidopterists. The results of this survey will be described later in detail; here we may note that it soon became apparent that a full understanding of the relationship between the different types of display could only be obtained by research in the field.

In addition, yet another problem had revealed itself: the neotropical hemileucine saturniid moths, whenever they settle into the rest position from flight, perform a rhythmic side-to-side "rocking" movement of the entire body, in which the head rotates through an arc around the longitudinal axis of the body, and the legs of each side are alternately flexed and extended. This striking movement was first described by Dr. Margaret Bastock and myself (Bastock and Blest, 1958) in the Brazilian *Automeris aurantiaca* Weymer. A detailed analysis showed that, if the variants introduced by age are controlled, essentially the strength of the rocking response, as measured by the number of oscillations performed, is influenced solely by the duration of the preceding flight performance, to which it bears a strictly linear relationship (fig. 1) (Blest, 1958). Now this relationship is of particular interest, for it is clearly very similar to that which the rhythmic components of the honey-bee communication dance bear to the distance flown between foraging ground and hive (Steche, 1957; Von Frisch and Jander, 1957). Since the bee dance is the only example of animal language that is comparable in its apparent achievement to our own, any evidence that may throw light on its physiological and evolutionary antecedents is of immense interest. Thus the causal basis of the moths' behavior had to be determined, as well as its role in communication or otherwise.

In fact, no definite answers to this last problem of function have been obtained; but, to anticipate, we shall see that the results of observations on the rocking response can be combined with a knowledge of the protective displays to yield a new approach to a wholly distinct and quite fundamental problem in modern biology: the

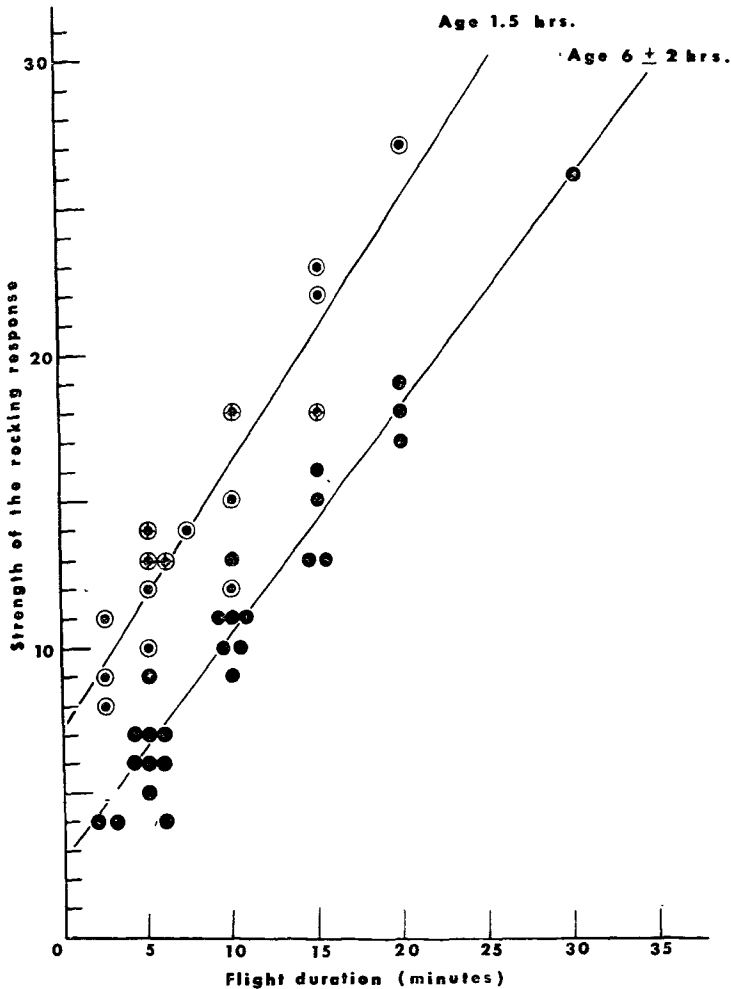


FIGURE 1.—The relation between the strength of the rocking response, measured as the number of oscillations of the side-to-side movement performed, and the duration of a preceding period of forced, tethered flight for *Automeris aurantiaca* at 1.5 hours, and 6 ± 2 hours after eclosion.

phenomenon of specific age. All, or nearly all, animals undergo senescent change; all ultimately die; and the duration of life, or, at least, the average pattern of longevity, is a property that is characteristic of a given species. Yet in no animal group have the mechanisms responsible for these neatly adjusted limitations of life-span been worked out.

At the beginning of July 1958, through the good offices of the Director of the Canal Zone Biological Area, Dr. Martin Moynihan, and aided by a grant from the U.S. National Science Foundation to the Smithsonian Institution, fieldwork on the Central American Saturniidae was finally started.

Barro Colorado Island lies in Gatun Lake. Consisting of some 13 square miles of seasonal tropical evergreen forest, it was established artificially when the surrounding area of lower land was flooded during the construction of the Panama Canal. The forest is intersected by trails, which are maintained by the staff of the research station, covering the whole island save for the clearing in which the living accommodation and laboratories are placed. The forest itself is not, as has sometimes been stated, virgin, for areas of it were under cultivation before it was taken over as a biological reserve in 1923. While for the botanist, therefore, the basic ecological status of much of the forest may appear questionable, for the zoologist, and especially for the invertebrate zoologist, the whole area is uniquely suitable for the investigation of tropical biology. To date the greater part of the intensive work carried out on the island since its inception has been faunistic; thus the necessary foundation for ecological research has been laid to a degree which probably no other New World tropical area can equal. Even so, discoveries can still be made even in the best-worked groups. The arachnids are among the best known of the island's invertebrates, thanks to the redoubtable efforts of Prof. A. M. Chickering: nevertheless I found three specimens of a ricinuleid near to *Cryptocellus emarginatus* Ewing living under stones in deep litter on the forest floor. While the order has been found, mostly as single specimens, in Honduras, Costa Rica, Nicaragua, and Colombia, this is the first record for Panama.

For the biologist who has been accustomed to the undemanding conditions of temperate woodlands, the inaccessibility of the greater part of the tropical fauna is disconcerting. Much of the copious insect life is confined to the forest canopy some 90 feet or more above the forest floor. There is an abundance of different species even within restricted taxonomic groups, and this prolific speciation is one of the most important and still imperfectly understood features of tropical zoology. In the course of a 6-month period, some 35 species of saturniid moths were attracted to lights placed in the laboratory clearing, and this tally by no means exhausted the known fauna of the area. Many of the species were common. Yet the picture yielded by attempts to search for the larvae was a very different one. Those of only one species, *Lonomia cynira*, were found commonly, and this because of their habit of resting in small groups on the trunks of slender second-growth trees, at a height of some 2 to 4 feet above the ground. Very occasionally the larvae of some six other species were encountered, generally as fully grown individuals in their last instar, when the initially gregarious caterpillars have scattered and are living singly on their food plants. Yet this meager harvest was the result of several weeks of quite frequent searching. Most of the larvae of

the 4,000-odd species of Lepidoptera recorded from the island may be assumed to feed in the canopy, where they are beyond the reach of the biologist. The rearing of tropical insects, too, is not made easy by the presence of their normal pathogens. To breed tropical saturniids in a European laboratory is paradoxically an easy business, for they will accept a wide range of substitute food plants and do not readily become infected with bacterial or virus disease. In the Tropics, the mortality from disease is high, and most species have specialized feeding habits which are not easily determined.

For the greater part of the work, then, the moths were attracted to photoflood lights placed on the outside walls of the laboratories. While a few moths would generally come to light on most evenings, the peak emergences always occurred just before the new moon. They did not fly uniformly throughout the night; there appear to be bursts of activity at localized times, the main flights occurring in particular at about 1 a.m. and 4 a.m. A given species, too, often has a preferred flight time, which in some cases may be highly restricted. *Dirphia* (*Periphoba*) *hircia*, for example, on Barro Colorado, tended to restrict its activity to the 4 a.m. flight, and on each night the whole flight of the small population near the laboratory was apparently completed within a 10-minute period. Most of the moths arriving at light were, from their perfect condition, quite clearly undergoing their first flight after emergence from the pupa, for when flying under tropical conditions these very large moths soon suffer conspicuous damage to their wings.

Conveniently, these moths are highly resistant to a wide variety of quite drastic experimental procedures. Usually, after capture at an environmental temperature of some 26° to 29° C. they were stored in an icebox at 6° C. overnight, yet comparison with individuals which had not been so stored showed that their behavior was in no way impaired by this treatment. After they had been allowed to warm up to the surrounding temperature, their display behavior was examined by gently stimulating them. Much of the actions that resulted was recorded on film and on 35-mm. color transparencies.

The protective displays of saturniid moths, unlike those of mantids, do not require very specific stimuli for their release. Four subfamilies are found on Barro Colorado: the Rhescyntinae, Citheroniinae, Hemileucinae, and Saturniinae. Of these four, only the Rhescyntinae and Saturniinae show any responsiveness when at rest to moving visual stimuli—shadows or solid objects in their vicinity, and the like. They will also respond to tactile stimuli, which alone elicit the protective displays of the other two subfamilies.

The protective behavior falls into the following main categories:

(1) Behavior which, teleologically speaking, is directed toward the quickest method of escape available to the insect. Thus, *Copaxa*

decrescens at rest shows a generalized resemblance to dead, brownish foliage. Tactile stimuli cause the moth to fly suddenly away, using the first depression stroke of its flight response to project it from the vertical substrate upon which it is resting.

(2) The use of eyespot patterns. These, in the New World Hemileucinae, are exclusively borne on the hind wings. The moths when at rest show a generalized resemblance to dead and folded leaves. When the moths are touched lightly, the forewings are moved forward to expose the eyespots. The moth may also make a series of little "hops" by performing depression flicks of the wings. The stages in such a display performance are illustrated in plate 2, figures 1 and 2. These eyespot patterns appear to "parasitize" the inborn responses of small avian predators to their own enemies. It has been shown experimentally that the simultaneous presentation of an eyespot pattern with a prey object will inhibit or delay the feeding responses of various small European passerines, and may even frighten them away (Blest, 1957a). This is not a very efficient form of protective coloration, for the individual predators soon become habituated to the eyespots and learn to ignore them.

(3) The acquisition of a nauseous taste or odor, coupled with an aposematic or "warning" display. Examples of these displays are shown in plate 5. Even within the Hemileucinae the nature of the nauseous material varies. *Dirphia* spp. possess an unpleasant, or, in the case of *D. (Periphoba)* spp., a foul odor, and nauseous body fluids and meconium. The advanced species of *Hylesia* are equipped with venomous hairs on the abdomen; so venomous, in fact, that in areas of Peru and Venezuela where certain species may, periodically, emerge in large numbers, there have been sporadic outbreaks of an eczematous skin condition caused by contact with the loose hairs.

It has been shown that birds can learn to avoid prey objects after no more than one or a few encounters, if the prey is sufficiently nauseous (see reviews in Cott, 1940, and Blest, 1957b), and experiments on Barro Colorado have shown that marmosets learn with similar rapidity. This is an efficient mode of coloration, for, by the sacrifice of a relatively small proportion of the population, the majority of the individuals are heavily protected. Generally, such species are equipped with conspicuous or gaudy coloration—striped or spotted patterns with a predominance of yellow, red, white, and black pigmentation; adaptively, this is certainly a device to improve the rapidity of the predators' learning processes.

Now, it is apparent that the efficiencies of these various protective devices are not equal. Habituation to eyespot patterns occurs rapidly; one might be tempted to suppose that the interpolated hopping movements must necessarily increase the intimidating effect of the display but this is not so. While some individual birds may become so

frightened of displaying moths that they will in the end wholly avoid them, others, perhaps the majority, after habituation reach a state in which the rhythmic movements act, as do most prey movements, to release attack. Thus the possession of rhythmic display components is not an unmixed blessing (Blest, 1957b), and these eyespot displays are possibly among the least efficient modes of protective behavior; they are, in fact, always lines of defense secondary to cryptic or procryptic coloration. These latter modes of coloration, when unaccompanied by secondary defense mechanisms, have their own typical protective behavior.

Moths possessing specialized procryptic behavior closely resemble objects found commonly in their environment, such as dead leaves, bark, etc., and their behavior is closely adapted to their coloration. They exhibit no display of any kind, and are unresponsive even to violent stimulation. They will, indeed, withstand interference to the point of mutilation without responding. One response to interference is, however, retained: the righting response. Moths placed on their backs in an inverted position right themselves by elevating all the wings so that their dorsal surfaces touch over the thorax. This is an adaptive procedure, for the procryptic patterns of the saturniids are confined to the upper surfaces of the wings in all but a few cases. Procryptic coloration and behavior necessitate certain correlated trends; for example, dispersion in the environment sufficient to prevent too frequent prey-predator encounters (de Ruiter, 1955).

Now the suggestion was earlier made (Blest, 1957b), on the basis of a small survey of the behavior of the world Saturniidae, that these various modes of display behavior were not evolved independently within the group, but were instead evolved as a series in which advanced species gained displays of high efficiency by modifying both their coloration and behavior from the primitive displays possessed by their ancestors.

The primitive display type was supposedly the simple rhythmic display, whose components were suggested to be derived from flight movements. The heavy-bodied members of the family are unable to fly from rest until they have first raised the working temperature of their thoracic muscles to some 35° C. by a period of "shivering." If they are strongly stimulated during the shivering process, they will perform more-or-less ineffectual flapping movements of the wings. It seemed reasonable to argue that the selection and stabilization of certain components of these flapping movements might have given rise to rhythmic displays, the subsequent modification of which yielded the remaining display types in this order: First, the eyespot patterns from which the rhythmic components are missing; next, as alternatives, cryptic coloration and behavior, and the various degrees of aposematic display. Finally, in the case of aposematic insects,



The typical resting posture of the Hemileucinae. A male *Automeris aurantiaca*.



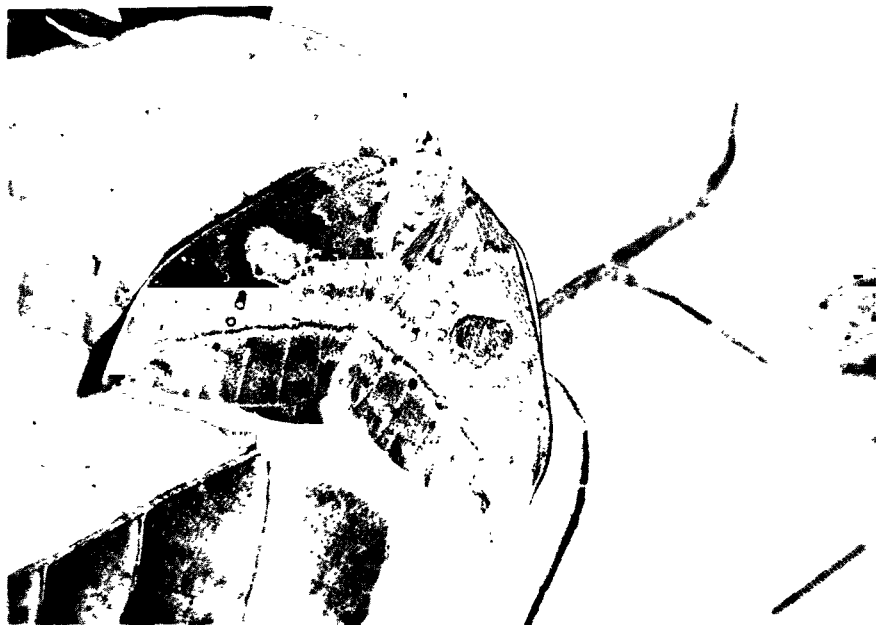
1. *Automeris liberia* performing a primitive rhythmic display. Note that the abdomen is concealed by the hind wings. Trinidad.



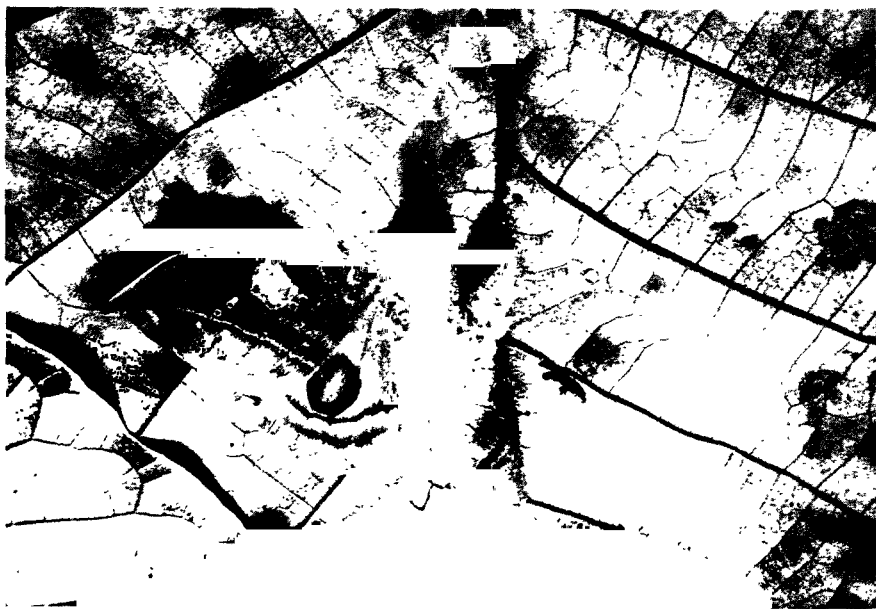
2. *Automeris egeus* performing a rhythmic display. Trinidad.



An unidentified *Automeris* spp., nr. *A. aurantiaca*, performing a static display, from which the rhythmic components have been eliminated. Note that the hind wings are protracted to partially expose the abdomen. Panama.



1. *Automerina auletes* at rest. Note the highly specialized cryptic markings. Panama.



2. *Automerina auletes* displaying after a tactile disturbance. Note the elevation of the wings, the curling of the abdomen, and the reduced eyespots. Panama.



1. *Dirphia* (*Periphoba*) sp. in display. Note the strong elevation of the wings, the curled and banded abdomen, and the protracted, pale antenna. Panama.



2. *Hyletia canitia* in display. Note the total elevation of the wings. The abdominal hairs are poisonous. Trinidad.

certain species in the genera *Eudyarina* and *Cerodirphia* appear to have acquired so great a level of distastefulness linked with generalized aposematic coloration that display has become unnecessary, and is no longer maintained by selection. Although individuals of these species show themselves capable of performing normal displays, in most they are either transient or absent; yet the existence of "perfect" displays in this small minority of individuals leaves no doubt that this elimination of the aposematic display pattern has been a secondary change.

A major aim, then, of the work on Barro Colorado was the examination of this evolutionary succession in a more narrowly defined range of species, by which it was hoped that the intermediate stages between the display types would be revealed. This rather optimistic expectation was, surprisingly, fulfilled; 21 species of hemileucines were found on Barro Colorado. Twelve more species were observed during a 6-week period spent in the Arima Valley of Trinidad, following a generous invitation from the New York Zoological Society to work for a period at their Trinidad Field Station. With the addition of 10 species seen as the result of purchasing live pupae from Argentina, Mexico, and Brazil, the total is now 43 species within this subfamily alone. This series is a particularly valuable one, since the Hemileucinae exhibit most of the major types of protective coloration found in the Saturniidae, and the interrelationships between them can be readily worked out. There is no space in this article to present the detailed arguments through which the evolutionary succession has been deduced, but the changes which are believed to have occurred are as follows:

The primitive display type within the Hemileucinae is, in fact, a rhythmic display, linked with hindwing eyespot patterns, in which the forewings are protracted following tactile disturbance to expose the eyespots, and the moth executes little hops by means of depression flicks of the wings. This type of behavior is found in a large number of species of the genus *Automeris* (13 out of the 20 species so far seen). The flicking movements are regularly spaced in time, at intervals of between 0.5 and 1 second, and the complete flick movement itself is completed within little more than one-tenth of a second. Analyzed with the ciné camera each flick is found to be a complete flight stroke appearing in isolation, and if the moths are very strongly stimulated, intermediates between true flapping flight and the ritualized display flicks can often be obtained. In some species of *Automeris* (e.g., *A. janus*), the flick movements are accompanied by quite perceptible "shivering" movements of the wings; the warming-up movements preparatory to flight have not been wholly eliminated from the displays. Since it is known that shivering movements by

themselves stimulate small birds to attack, it is reasonable to suppose that selection should act to eliminate these movements, and such has been the case.

The next stage in the evolutionary succession is a simple one: the elimination of the rhythmic components, which has been achieved merely by raising their threshold. Some species, for example, *A. memusae*, perform the rhythmic part of their display to very light tactile stimulation; others (e.g., *A. coresus*) require strong tactile stimulation before it can be elicited, even to the point of mutilation. Further species, such as *A. tridens*, appear to be behaviorally polymorphic. Some individuals of a population can be made to "hop" if violently treated, others cannot, and the differences are individually consistent over periods of days; finally, some species (e.g., *A. godarti*) never perform a rhythmic display.

Meanwhile, certain other changes have been taking place. Whereas no species of *Automeris* is highly unpalatable, there are at least differences in their degree of acceptability to predators. *A. foucheri* is eaten readily by coatis and by the relatively unfastidious marmosets. *A. junonia* is accepted by marmosets but rejected by coatis. Whether this trend toward unpalatability is another aspect of the changes in the display pattern is not yet certainly known, but it seems likely. Certainly, an increasing feature of the more specialized displays is the introduction of curling components of the abdomen. In the species with full eyespot displays, this component merely tends to increase the apparent size of the displaying moth. But, ultimately, it becomes linked with another evolutionary trend, the reduction and, eventually, the elimination of the eyespot patterns themselves. Now in some species, such as *Automeris aurantiaca*, the eyespots have become reduced; the abdomen, on the other hand, is more strongly curled during display, and especially so in females, whose abdomens are so swollen with eggs that, curled, they present a series of greenish-white bars (the egg mass shining through the intersegmental membrane). The hindwings are also protracted so that the abdomen is made visible from above. There is also a tendency for both pairs of wings to be somewhat elevated. In more highly evolved species (e.g., *Automerina auletes*, *Hyperchiria nausica*) the abdominal curling is yet more marked, and the wings are even more strongly elevated, now exposing the lateral aspects of the abdomen while not wholly concealing the small eyespots.

This little series has been followed out in a very restricted group of closely related genera. The next stages are not found in this group, but appear to follow from it so logically that there is no doubt of their starting point. The genus *Hylesia* contains a large number of small brownish moths, clearly derived from the *Automeris* group of genera, probably from *Gamelia* (Michener, 1952). Most,

but not all, of the species are equipped with poisonous abdominal hairs. The species which independent characters indicate to be the most primitive possess extremely tiny vestigial eyespots. In *Hylesia nanus*, at least, these are not exhibited during the display, for the wings are so strongly elevated that their dorsal surfaces touch over the insect's back. Here, however, there is no abdominal curling component. In the vast majority of *Hylesia* the eyespots have been eliminated altogether, the abdominal curling components are exaggerated to the point at which the terminalia are approximated to the ventral surface of the thorax in display, and the insects are definitely distasteful, for they are rejected by marmosets and coatis. Throughout these displays the antennae, which are small, are kept retracted against the sides of the thorax, where they are concealed among the concolorous thoracic hair. The final episode of evolutionary history, in which the antennae are incorporated into the displays, again necessitates a jump to a further group of genera, that containing *Dirphia* and its allies.

These moths do not possess poisonous hairs, but they are malodorous, and in palatability tests with marmosets and coatis, unequivocally distasteful. They are also tough. While few *Automeris* will withstand a bite from a marmoset without suffering disablement, the moths in the present group will withstand a great deal of interference without distress. Primitively, the antennae are small and not exhibited during display (e.g., *Molippa simillima*, *M. latemedia*, *Dirphia* (*Dirphiopsis*) *eumedeide*, *D. (D.) agis*). In *Dirphia* (*Dirphia*) *avia*, they are protracted throughout display, and are relatively larger. In *D. (Periphoba)* spp. they are very much larger, bright lemon yellow, and clearly serve as an aposematic signal in themselves. Finally, in this group, as we have seen, the degree of distastefulness has apparently reached a point at which over-all aposematic coloration independent of display has become a possibility, and sustained displays are no longer performed. The whole series is summarized in plates 2-5.

Thus all the hypothetical stages in a long series of evolutionary change have been found to be present in contemporary species, so neatly dovetailed that we can have confidence in their validity. While they may be extended to include the various other types of protective coloration, to do so would require a discussion of some of the other saturniid subfamilies in which the best evidence is to be found, and for this there is no space in this article.

Now the mode of protective coloration should have one important potential evolutionary consequence which has hitherto been overlooked: the modification of lifespan. Once the individual insect's reproductive life is over, its further fate as an individual might be supposed to exert no influence upon the survival and reproductive

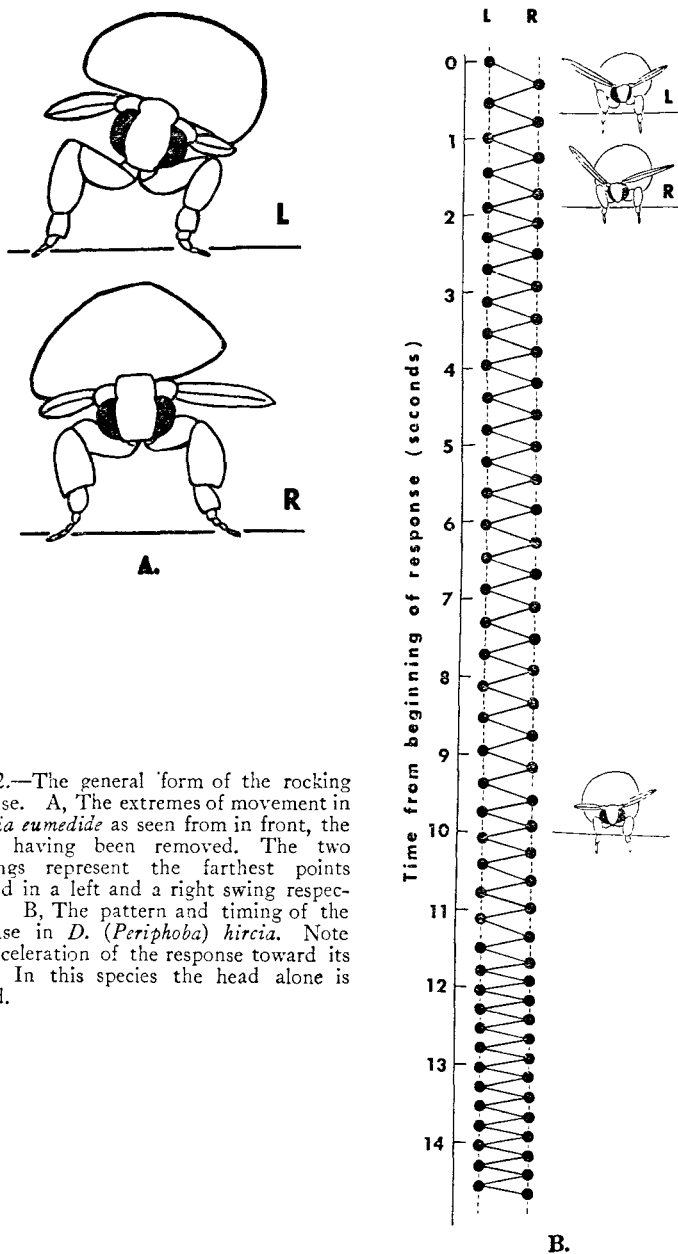


FIGURE 2.—The general form of the rocking response. A, The extremes of movement in *Dirphya eumelide* as seen from in front, the wings having been removed. The two drawings represent the farthest points reached in a left and a right swing respectively. B, The pattern and timing of the response in *D. (Periphoba) hircia*. Note the acceleration of the response toward its close. In this species the head alone is moved.

capacity of the species as a whole. In fact, it has been argued (Medawar, 1952) that, in most cases, the decline in reproductive potential with age is necessarily accompanied by a decrease in the selective forces acting on the individual. Exceptions to this generalization have been recognized in the social animals, where group selection can act to lengthen the postreproductive life of individuals whose

experience is of value to the social unit. Despite the plausibility of this argument, and the clear evidence for the action of group selection which the elaborately differentiated sterile castes of the social insects unequivocally present, Williams (1957) has dismissed the role of group selection as an important factor in the modulation of postreproductive longevities.

The types of protective coloration that have been described above all have one feature in common: they impose patterns of learning upon the predators against which they are directed. Consider the outcome, first, of an encounter between a naive predator and a palatable procryptic prey. The loss of the individual prey cannot influence the reproductive capacity of the residual prey population directly; but the predator has now learned to a greater or lesser degree how to find more preys, and the lesson must act to the disadvantage of the prey population. The probability that the predator population will learn to find preys will be increased the longer the preys live. Thus, if group selection is able to act, we must expect it to reduce the postreproductive longevity.

Conversely, an unpalatable aposematic postreproductive prey trains the naive predator to avoid other members of the population, and group selection should act to augment their postreproductive lifespan. How well do the hemileucines fit in with this evolutionary scheme?

In the first place, group selection can surely act in this case: hemileucine females lay their total complement of eggs in batches, over a period of from one to a few days. The larvae are typically gregarious until the final instars, grown synchronously, pupate at about the same time, and emerge over a period of a few days in phase with a lunar cycle. Thus the siblings derived from each female are available at the same time in the same ecological areas for the action of group selection.

So far the data available appear to support the hypothesis well: the procryptic *Lonomia cynira* is short lived—at 26° to 29° C. none out of 40 odd individuals hatched from pupae lived for longer than 4 days, and most had died by the third day from eclosion. The distasteful *Dirphia* (*Periphoba*) *hircia* is long lived, certainly for 10 to 14 days after capture, and similar longevities have been noted for *D.* (*Dirphiopsis*) *eumedide* and *D.* (*D.*) *agis*. However, this part of the hypothesis may only be reliably tested when more data, obtained under controlled conditions, become available from further field and laboratory studies. As far as life tables are concerned, at the moment we have none, but there seems to be every hope that they will bear out the present tentative hypothesis.

We can, however, use the rapidly accumulating information about the significance of the rocking response to provide a speculation about

one of the paths through which the hemileucine lifespan appears to be limited. The general form of the response is shown diagrammatically in figure 2. In intact, free moths it is normally performed whenever the insects settle into their stereotyped resting position, whatever the nature of the preceding activity. All that is required for its release is a contact stimulus to any one of the six tarsi. The number of oscillations of the rhythm is readily counted with the naked eye, and may be used to give a measure of the strength of the response. Moreover, the coordination and release of the rocking pattern are not prejudiced by quite drastic surgical procedures involving gross mutilation of the moth. Thus it is peculiarly susceptible to exact laboratory analysis. The full details of this work are to be published elsewhere (Blest, in press); although the experimental procedures are made somewhat complicated by the presence of interactions between the patterns of oviposition and display, in addition to those of flight and settling, the picture given by the interaction between the last two responses is a simple one. The strength of the rocking response is basically determined by two factors alone: (1) The duration of the individual's preceding flight performance (fig. 1); (2) the age from the act of eclosion from the pupa, the strength of the response diminishing with age. Now, by a happy accident, the species of *Automeris* which happened to be freely available for experimental work, *Automeris aurantiaca*, is one whose display behavior is intermediate between a typical eyespot display and an aposematic display of the *Dirphia* or *Hylesia* type, and, to a great extent it shares the toughness of these aposematic insects. It is peculiarly resilient to experimental interference; moths have been flown and tested for the strength of the rocking response after removal of the abdomen, the replacement of their blood by Ringer's solutions containing various amounts of added blood sugars, the removal of their antennae and of the wind receptors of the head, and the complete section of the indirect flight muscles and bilateral excision of the wing bases. None of these procedures prejudices the relation between flight performance and the strength of the rocking response. From this and other evidence of a more complex and less direct nature, we can conclude that these interactions are controlled by the central nervous system without any feedback from the state of metabolic reserves, or from the exteroceptive or proprioceptive consequences of flight being involved; all that is required for the *registration* of flight performance in the central nervous system and its subsequent *expression* in terms of the rocking response is that the normal pathways for the elicitation and maintenance of flight should be stimulated, and that flight itself should be performed. In the experiments that have just been inadequately outlined the moths were suspended during flight from artery forceps holding a small pinch of the abdominal cuticle; yet the in-

cremental course of the rocking response did not differ from that found in free-flying moths. If the moths are suspended and receive the appropriate stimuli for flight without flight being released (preparations may, for a variety of reasons, become refractory), the rocking response does not increase in strength. What is being registered, therefore, is the duration of the activity of some part of the central nervous system which excites and regulates the flight response. This situation is of peculiar interest because the rocking response is stable to retesting for periods of at least 90 minutes, and probably for longer; hence, the whole process of registration is comparable in some respects to a learning process in that a stable change is imposed upon the nervous system. It differs from conventional learning processes in that there is no problem of perceptual filtering to complicate the issue, and the quantitative and qualitative nature of the output is rigidly determined. While this simplicity and rigidity may be formally inconvenient for the learning theorist, it offers experimental advantages for an attack on the physiology of learning processes which it is hoped may one day be put to proper use.

However, it is a different aspect of the rocking response which bears upon the problem of lifespan.

A statistical analysis of the relations between rocking pattern and other responses has shown that it is linked to a system that exerts an inhibitory "brake" action on flight behavior. Apparently the strength of the rocking response is in some sense a measure of the strength of this inhibitory potential. If the rocking response is strong, then the threshold of the flight response tends to be high and its persistence poor. Although these parameters of flight performance have not yet been placed on a firm quantitative basis in relation to the rocking potential, it is already apparent that in this respect the quantitative implications of the rocking response are considerably less strict than in the case of the relationship to flight performance per se. Now the strength of the rocking potential follows a definite course with age. Immediately after hatching from the pupa it is strong; thereafter, it falls off, most steeply in the few hours that immediately follow the act of eclosion from the pupa. Moreover, the slopes of the regression of rocking response on flight time (fig. 1) also fall off (fig. 3). Thus, ultimately, an age is reached at which (a) no overt rocking movement can be performed, and (b) all flight durations would, in principle, in any case yield the same rocking strength, for the regression coefficients have fallen to zero. Since the rocking potential is held to be linked to an inhibitory potential, it may be argued that the conclusion of these age changes in the rocking response should see the total disinhibition of flight.

Hemileucine moths do not feed, and their mouth parts are, in fact, vestigial; they are partially closed metabolic systems, and their life-

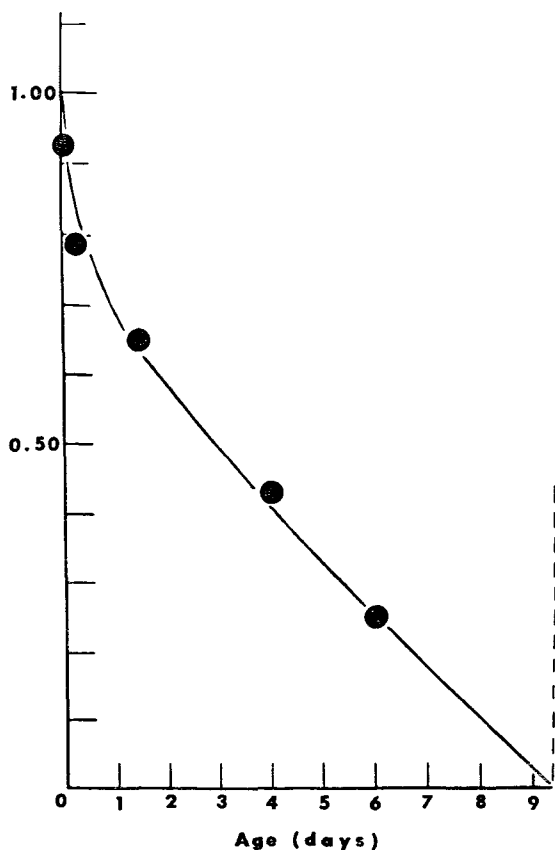


FIGURE 3.—The relation between the regression coefficients of rocking response strength on flight time and age from eclosion. (See also fig. 1.)

spans have a necessary upper limit which is determined by their food reserves at hatching. The relaxation of the brake on flight behavior must result in an immediately ensuing consumption of metabolic reserves, which will prove fatal. An upper limit to the hemileucine lifespan, then, is set by a physiological "clock" located in the central nervous system, and it is reasonable to examine the possibility that selection has acted upon the characteristics of this clock to modulate the longevities of different species.

So far the available information is in excellent accord with this general hypothesis. For *Automeris aurantiaca* the calculated upper limit is about 9 to 10 days at 20° C., which is in good agreement with the order of the lifespan observed at this temperature. Although in virgin females flight behavior is blocked by inhibition from competing reproductive responses, namely, the assumption of the specialized calling posture in which receptive females await the arrival of mates, the death of males is preceded by just that burst of violent and un-

regulated flight behavior which the present theory demands. Similarly, in the period immediately before death, a mere 2 to 3 days after hatching, the procryptic *Lonomia cynira* shows similar unregulated activity. And, as we would expect, the rate of decay of the inhibitory "clock," as measured by the changes in the rocking potential, is extremely fast. Overt rocking responses in this species may disappear by the end of the second day from hatching. Conversely, in the long-lived and aposematic *D. (Periphoba) hircia*, the rocking potential declines extremely slowly, and strong rocking responses can still be observed as much as 10 days after capture.

However, we still require exact measurements of the characteristics of these clocks; and, as yet, there is nothing known as to the way that sexual activity may modify their performance, although there seems to be a possibility that it may do so. Certainly this is a very special case: even in the closely related Citheroniinae and Saturniinae there seems to be no parallel to this clock system. For ourselves the concomitants of the aging process present a familiar picture of failing sexual powers, increasing rigidity of outlook, and overall physical deterioration; the hemileucines, on the contrary, expire in a final blaze of hyperactive glory. Why then, should their aging and death so particularly interest us?

The answer to this is twofold: First, as has already been mentioned, no previous biological material has been able to suggest precise paths through which natural selection can act to alter longevities. It has generally been assumed that selection, where it is able to act, must of necessity tend to lengthen lifespans (Williams, 1957). The recognition that, given an initially restricted lifespan, the mechanisms of aging may be of such a kind as to allow selection to modify the rates at which they proceed in either direction, may open the way to a more rationally planned approach to some of the problems of causation. Second, the apparent limitation of the lifespans by a neural clock implies that in this case the phenomena of specific lifespan are perhaps controlled by a unitary leading process. Now this process is certainly one which is unlikely to have any very general application in the animal kingdom. Attempts are still being made to provide general theories of senescence; examples such as that of the Hemileucinae stress the difficulties attending these oversimplified assaults upon what is beyond doubt a complex and specifically variable problem.

This report has had to cover a good deal of ground in a somewhat perfunctory manner, and it may be felt that some of the speculations go too far beyond the existing evidence; it is, in fact, less a report than a blueprint for future research. The justification for these extravagances lies in the way in which the whole course of this work illustrates the often fortuitous advantages that may be derived from a broad evolutionary study conducted in a tropical environment.

What was originally to be a simple survey of the modes of action of protective devices and their evolutionary consequences has developed in such a way as to bear upon quite distant issues of fundamental interest. Laboratory workers sometimes hold that the further exploration of comparative studies is not likely to yield much new insight into basic problems. This work provides an example of the manner in which a comparative field study can suggest the types of biological material best suited to the solution of the difficulties posed by special areas of research.

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Evolution of Knowledge Concerning the Roundworm *Ascaris lumbricoides*¹

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[With 2 plates]

No HELMINTH is more familiar to laymen than the large intestinal roundworm that bears the name *Ascaris lumbricoides*. An intimate companion of man since time immemorial, and known to Hippocrates as the most conspicuous member of man's intestinal worms, *A. lumbricoides* was baptized in a zoological sense, along with its host *Homo sapiens*, in 1758—the date which marks the beginning of binomial zoological nomenclature. In recent years the long-sustained association between this nematode parasite and man has been considerably weakened, if not severed, wherever sanitary barriers have been interposed between the two. If the parasite has practically disappeared from its human host in urban and other well-sanitated areas, it still lives on a lavish scale in the populations of several continents, where millions of people are continuously exposed to its attacks at an apparently undiminishing rate.

PREVALENCE OF ASCARIS

Throughout the Middle Ages—probably also long before that time—and extending well into the 19th century, *Ascaris* was a widespread parasite of man practically throughout Europe. According to Stoll's (25)³ estimate of the extent of the current human helminthic infections throughout the world, *Ascaris* is of more common occurrence than any of the other worms known to parasitize man. Stoll concluded that nearly 650 million human beings, about one-fourth of the estimated world's population, serve as hosts to this helminth. Of those so affected, about 75 percent live in Asia. A little less than one-third of the remaining 25 percent live in Europe, and about as

¹ Theobald Smith Memorial Lecture given at a meeting of the New York Society of Tropical Medicine, May 21, 1959, in New York City.

² Retired December 1, 1959.

³ Numbers in parentheses indicate references in the bibliography.

many live in the Western Hemisphere. The others are located mainly in Africa. The *Ascaris*-infected persons in the Americas are largely confined to Middle and South America. Those resident in North America constitute only about 6.5 percent of the affected persons in the Western Hemisphere.

That *Ascaris* was frequently seen in Europe in previous centuries, despite its concealed habitat in the small intestine, was due to its migratory habits, especially during fever, coupled with its conspicuous size. Its natural passage at times from the alimentary canal, and its expulsion following anthelmintic medication, a practice to which physicians had to resort very often in those days, made the worm a rather familiar object to doctors and patients alike. The spontaneous passage of *Ascaris* from the body was observed in outbreaks of plague, cholera, dysentery, typhoid, typhus, and other febrile diseases. Its spontaneous exit from the body in the early stages of typhus was regarded as a more or less grave prognostic sign.

Ascaris has been observed to pass out not only through the anal opening, but also through the mouth and nostrils, and sometimes through the ears. In fact, the older medical and parasitological literature, and that emanating from tropical countries to this day, contain harrowing accounts of intestinal obstruction by these worms, their occurrence as adults in the peritoneal cavity, the vomiting of them by children, and, occasionally, the strangulation of youngsters by the worms getting into the trachea and bronchi. In the course of a few days or weeks, as many as dozens, or even hundreds, of worms were reported to have passed out through various openings, while others that remained behind were recovered later after anthelmintic medication. No wonder, therefore, that *Ascaris*, along with other intestinal worms, was regarded during the centuries when there were practically no barriers to its unrestricted propagation and transmission from one human host to another, as the cause of severe illness and death. As a matter of fact, all the then known intestinal parasites of man were considered to be incitants of practically all diseases for which no other cause was apparent.

Some of the helminths that parasitize man have a more or less restricted geographical distribution, conditioned by such factors as availability of intermediate hosts, and the hosts' dietary and other habits, as well as temperature, humidity, and other environmental factors. Others have a less restricted distribution and occur wherever their hosts exist. There is no helminth, however, that has a wider distribution the world over than *A. lumbricoides*. Its extracorporeal existence apparently encounters no external environment so utterly defeating and no climate so extreme as to check altogether its unrelenting push from host to host.

Ascaris has been found, sometimes in abundance, in human inhabitants of cold climates, such as those that prevail in Finland, Greenland, Scandinavia, and other northern countries. However, a warm, moist climate is ideal for the persistence of its eggs, and affords, moreover, optimum conditions for their development. It has long been known that the Tropics afford a haven to these worms. The habits of the people there and their substandard hygienic practices, coupled with a level of sanitation that is incompatible with healthful living, almost preclude a complete escape from the invasion of these parasites. A century or so ago medical observers were struck by the almost universal occurrence of *Ascaris* in Negroes living in the American Tropics, especially in French Guiana. There the population—adults as well as children—was practically never free from *Ascaris*. Literally, several hundred worms were observed to have been voided by children in the course of a few days. In autopsies, large numbers of *Ascaris* were found in the intestines, regardless of the disease to which the subjects had succumbed. So huge were the masses of worms seen during autopsies that they were referred to as “hatfuls of worms.” That huge accumulations of these helminths did not altogether disappear in more recent years is evident, for example, from the fact that in 1950 there was reported, in an article published in the *Transactions of the Royal Society of Tropical Medicine and Hygiene* (28), the recovery of more than 2 kilograms of adult ascarids from the intestine of an Arab boy in Iraq, who died from an intestinal occlusion caused by an entangled mass of these worms. Reports of massive infections with these parasites are still seen currently in medical journals that emanate from the American and other Tropics, as are also reports of rather unusual lesions caused by these worms.

ALLEGED SPONTANEOUS GENERATION OF ASCARIS

Before the classic experiments of Redi (19) in the 17th century, the spontaneous generation of metazoan organisms, such as snails, flies, and other insects, and especially intestinal helminths, was generally accepted on the basis of long tradition backed up by no lesser authority than that of Aristotle. According to Redi, even William Harvey expressed the belief “that all living things derive their origin either from semen or eggs, whether this semen have proceeded from others of the same kind, or have come by chance or something else.” Redi’s demonstration that flies did not develop from putrescent flesh kept in closed containers did not altogether close the issue of spontaneous generation of metazoan organisms. Old beliefs are not easily surrendered. The spontaneous generation of intestinal worms was long adhered to even by Rudolphi and Bremser, outstanding helminthologists of the 18th century. Writing in 1857, Küchenmeister (11) referred to the persistence of opinions on spontaneous generation, at

least in some quarters in France, as late as 1853. He quotes from a then current article the following view on the origin of ascarids:

In the predisposition to worms, the thick mucus of the intestine comes under our consideration in the first place, as, being acid itself, it cannot purify the blood from acids. From a portion of the mucus the worms are produced by *generatio aequivoca*, with the assistance of asthenia and adynamia. The worms produced, as the analysis shows, are still more acid than the mucus, from which they are produced. Emetics, drastic purgatives, mercury, antimony, and arsenic, certainly kill the worms, but weaken the constitution, and thus actually rouse the *generatio aequivoca* into activity, and thus actually cause the formation of worms.

This was perhaps the last stand to uphold the thesis of the spontaneous generation within the body of intestinal helminths—a view that had already crumbled for the most part before the scientific onslaught initiated by Redi almost two centuries earlier. It was Redi who discovered sex and eggs in *Ascaris* and made observations on the reproductive organs of this worm.

RESISTANCE OF ASCARIS EGGS

The remarkable adaptability of *Ascaris* to external conditions of all kinds is due in a large measure to the "toughness" of its eggs—the connecting link between the generations of worms. So great, in fact, is the impermeability of the egg shells, that "their development is not arrested in spirits of wine, chromic acid, or oil of turpentine" according to Heller (9) who investigated the embryonation of the cat ascarid nearly a century ago. In the laboratory *Ascaris* eggs are routinely cultured in a 2-percent solution of formalin, or in solutions of potassium bichromate, and they are said to have been cultured successfully in solutions of hydrochloric, sulfuric, nitric, and acetic acids, in strengths up to 50 percent, and in other solutions known to be highly deleterious to living matter.

Parallel to the resistance of the eggs to inimical environmental influence is the long persistence of the embryos within the egg shells. A number of investigators have reported eggs still containing living embryos after months, or even after years, of cultivation. Epstein (3), in Prague, infected children with eggs that had been kept in culture for a year. Davaine (1, 2), in France, in the second half of the 19th century, carried out his classic experiments with rats to which he fed *Ascaris* eggs that still contained viable embryos that hatched in these rodents, despite the fact that the eggs had been maintained in culture for 5 years.

At temperatures near freezing the development of the eggs does not progress. If development already has begun, it comes to a standstill at a temperature a few degrees above freezing, only to be resumed, however, when the temperature rises. The eggs are resistant, more-

over, to ordinary drying because the chitinous layer which envelops the shells affords additional protection against desiccation.

DEVELOPMENT OF ASCARIS EGG

Let us now turn our attention to the development of the microscopic *Ascaris* egg—the starting point in the long and tortuous climb that constitutes the life cycle of this helminth. After escaping through the uterine opening of the female worm in the host's intestine, and becoming incorporated in the intestinal contents, the egg is eliminated to the outside with the feces. There it is ready, so to speak, to face the perils of a free-living existence. Under favorable environmental conditions (a temperature of about 80° to 85° F., free access of air, and some moisture), it begins to undergo cleavage (pl. 1, fig. 1), and in the course of 2 to 3 weeks, a vermiform embryo (pl. 1, fig. 2), performing more or less constant gliding movements within the shell, especially when stimulated by heat, may be readily observed even under the low power of a microscope.

Up to about the middle of the 19th century there was no information on the development of the *Ascaris* egg, or on the mode of its transmission from one host to another. According to the best available sources, Gros (8), in 1849, working in Moscow, recorded observations on the development of *A. lumbricoides* eggs, which he had maintained in an incubator at a temperature of 15° to 16° C. from the 4th of August to the 2d of December. Three years earlier Richter (20) determined that *Ascaris* eggs remained alive in water for a long time and observed, moreover, that those so maintained for 11 months contained embryos. In 1853 Verloren (26) reared the eggs of the cat ascarid to the embryonated stage in only 15 days, and Heller (9) observed that the embryo casts its sheath while still within the shell. It was not until 1857, however, that Leuckart (12), at that time undoubtedly the most prominent of all helminthologists, made observations on the development of *A. lumbricoides* eggs—observations which have been sustained ever since. He determined that the speed of development varied considerably and was conditioned principally by the temperature of the environment. During the winter months there was little evidence of development, but during the warm summer embryogeny was speeded up to such a point that the embryo was already formed in about two weeks. He stated also that drying arrested development but the addition of a little water reactivated embryonation.

MECHANISM OF INFECTION

A logical sequence to the determination of the course of development of the *Ascaris* egg was to study its mode of infection. The

early attempts in this direction by Richter, Küchenmeister, Leuckart, and others yielded indecisive, or negative, results. Having failed to infect a rabbit and a dog after the feeding of the embryonated eggs, Leuckart carried out additional experiments with pigs, horses, and dogs to which he administered the eggs of their respective ascarids. He even swallowed the eggs of *A. lumbricoides* repeatedly without experiencing symptoms or becoming a host to the worms. Leuckart's tests with animals as well as those carried out by several of his contemporaries yielded almost consistently negative results.

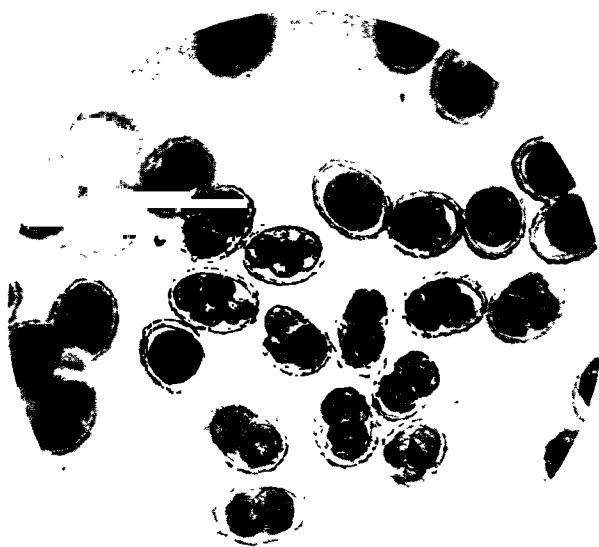
The most significant of the early experiments on the mode of transmission of *A. lumbricoides* was carried out, at Leuckart's (12) suggestion, by Mosler in 1860. Having failed on 12 different occasions to infect himself or others after the ingestion of the eggs, Mosler experimented on several children. They were given gradually increasing doses of eggs without, however, exhibiting clinical symptoms, except in one or two cases, in which the children became sick with pulmonary symptoms accompanied by fever. In the light of our present knowledge of the course of infection and early migration of *Ascaris* larvae, these symptoms were certainly suggestive of pulmonary ascariasis.

Another experimental infection was reported by Grassi (7) in a German publication issued in 1888. Briefly, in July of 1879, while he was professor of anatomy at Catania, Sicily, he swallowed several hundred *Ascaris* eggs containing living and "ripe" embryos. The eggs had been collected 9 months earlier from the intestine of a human cadaver, and cultured during the intervening period in feces kept moist by the addition, from time to time, of several drops of water. Thirty-three days later he observed ascarid eggs in his feces, and continued to find these eggs consistently for a long time thereafter. As reported by Grassi (6), his pupil, Calandruccio, also swallowed repeatedly embryonated *Ascaris* eggs but failed to become infected. Calandruccio succeeded, however, in infecting a 7-year-old boy whom he freed by anthelmintic medication of the ascarids he already harbored. After assuring himself, by repeated examination of the boy's feces during a period of several weeks, that he no longer passed eggs, he gave the lad a capsule containing more than 150 embryonated eggs. For the ensuing 20 days all fecal examinations made on this subject yielded negative results. These examinations were suspended until the 60th day after the inoculum had been given. On that day eggs were discovered in the boy's feces. About a month later, the boy, who had shown no symptoms in the meantime, passed spontaneously 143 ascarids measuring from 18 to 23 cm. long.

The experiment carried out by Grassi is open to question because the 33-day period that intervened between the date of infection and the first appearance of eggs in the feces is short by at least 2 weeks or more

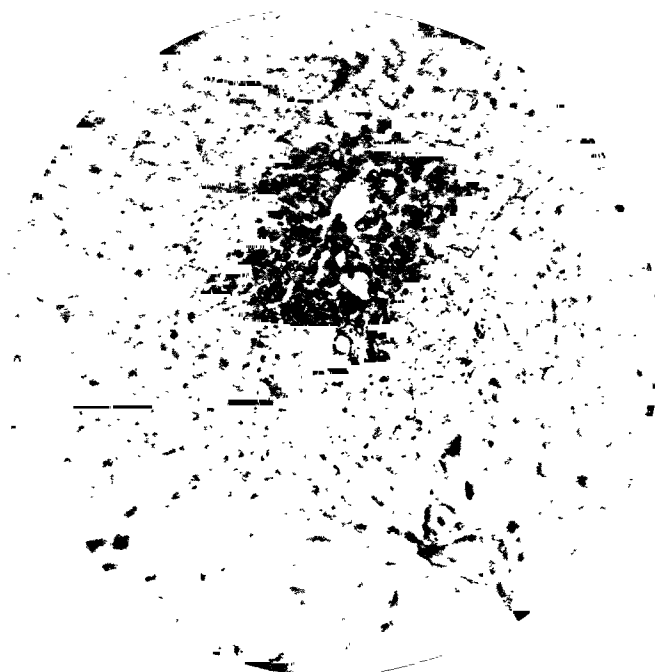


2. Embryonated (infective) *Ascaris* eggs. (Enlarged about 200 times.)



1. Early developmental stages of *Ascaris* eggs. (Enlarged about 200 times.)

27



1. *Ascaris* larva in guinea-pig liver. (Enlarged.)

25



2. *Ascaris* larva in lungs of guinea pigs. (Greatly enlarged.)

for the development of *A. lumbricoides* to a state of fertile maturity. According to several investigators, the minimum period of the pig strain is 49 days, and of the human strain even longer. The results of Calandruccio's experiment on the 7-year-old boy may be accepted as valid because the interval between infection and the discovery of eggs in the feces was 60 days. Moreover, the worms that the boy passed about 3 months after experimental infection were of a size corresponding to worms of that age, according to observations I made on the growth rate of *Ascaris* in the pig.

The successful results reported by Grassi found strong support in Lutz's (15) observations in Brazil on the epidemiology of human ascariasis. Lutz concluded from a study of the environment in which *Ascaris*-infected persons lived that this parasitic infection was in the main soilborne, and not, as others before him had supposed, waterborne or foodborne. Moreover, Lutz (16) carried out an experiment with a human volunteer, aged 32. This individual had been free of *Ascaris* for a period of 20 years, and lived in surroundings where he could not possibly acquire this parasite. The volunteer ingested in a period of 23 days small numbers of eggs on eight different occasions. He experienced rather severe abdominal pain, and also developed a bronchitis which probably was associated with the invasion of the lungs by *Ascaris* larvae—a link in the chain which constitutes that developmental cycle of the worm that had not yet been discovered at that time. He was given anthelmintic medication 28 days after the first ingestion of eggs, and passed a total of 35 worms, measuring from 5.5 to 13 mm. in length. The worms were identified as *Ascaris lumbricoides* not only by Lutz but also by Leuckart, to whom they were sent.

Epstein's experiment, in 1892, with three children, 4½ to 6 years old, was more convincing than any of the previous attempts to bring about an experimental infection with *Ascaris*. Although the practice of subjecting children to medical experiments must be severely condemned, Epstein, by meticulous planning and painstaking observations, demonstrated beyond doubt a direct development of *Ascaris* from the embryonated egg to the adult, egg-laying worm in 10 to 12 weeks.

It is evident from the foregoing account that early in the last decade of the 19th century the basically important facts as regards the mode of transmission of *A. lumbricoides* had been ascertained. It must not be supposed, however, that all investigators accepted the idea of a direct development of the worms in one host up to the stage of egg-laying maturity. At first, Leuckart came to the conclusion on the basis of repeated failures by himself and others to infect man, the horse, the pig, the dog, and other animals with their own or related species of ascarid, that these worms apparently had

an indirect life cycle. He assumed that some terrestrial invertebrate—an insect, slug, snail, or other creature, not even excluding a mammal—harbored the intermediate stage which, he supposed, developed in it from the embryonated eggs it had swallowed, and that man became infected by accidentally eating with a salad, for instance, the alleged intermediate host. Von Linstow (14) actually pointed the finger of suspicion at myriapods that were abundant in vegetable gardens in Germany, and he assumed that the accidental ingestion of these invertebrates, especially by children, could account for the acquisition of the worms. Leuckart (13) finally receded from the position that *A. lumbricoides* was a heteroxenous nematode, partly because he failed, despite repeated efforts, to find an intermediate host, but also because he was convinced that the epidemiological and experimental evidence marshaled by Lutz (15) did not support his assumption of an indirect life cycle.

A new method of approach to the experimental study of the mode of infection of *A. lumbricoides* was introduced by Davaine (1, 2) by using a rat as a test host. Twelve hours after administering in milk a large number of embryonated *Ascaris* eggs to a rat, this animal was destroyed and its digestive tract slit open and carefully examined. Although the eggs so administered had been kept in water for a period of 5 years, they were still alive. At autopsy of the rat, unhatched eggs were still present in its stomach and duodenum. In the jejunum, and especially in the ileum, Davaine found living larvae that had extricated themselves from the egg shells, and some that were in the process of so doing through a perforation at one of its poles. The empty shells were ruptured but not digested. In experiments with another rat, Davaine observed living larvae that had passed out with the feces. From these experiments he inferred that *Ascaris* eggs probably would hatch in the human intestine, and the liberated larvae would grow to maturity there, without the intervention of an intermediate host postulated by Leuckart and von Linstow.

NEWER KNOWLEDGE OF LIFE CYCLE

And so matters stood until 1916. In that year, Capt. F. H. Stewart (23, 24) of the Medical Corps of the British Army, was stationed in Hong Kong, where *Ascaris* was very common in children and in pigs. Stewart published in the July 1, 1916, issue of the British Medical Journal an account of a series of remarkable experiments that gave an insight into the developmental cycle of *A. lumbricoides* that was far different from that anyone had ever suspected. In fact, his experiments, as subsequent events showed, made it possible, for the first time, to place a correct interpretation on the results of Mosler's experiments with one or two children who became ill with pulmonary

symptoms following inoculation with *Ascaris* eggs, and a similar experiment by Lutz (16) in Brazil.

Having failed in 1915 to infect two young pigs with the embryonated eggs of the human and swine *Ascaris*, Stewart turned his attention in 1916 to Davaine's approach to the solution of the *Ascaris* life history, by experimenting with rats and mice. He inoculated rats, using in succession the eggs derived from the human and pig hosts on the same test animals. Less than 24 hours later live larvae were found in the feces of the rats, and continued to appear there for some days. The larvae moved in a languid manner, and were still alive 3 days later, after having been kept at a temperature of 25° to 30° C. On autopsying one of the rats which died 6 days after the first inoculation, while the companion rats involved in this experiment were showing symptoms of pneumonia, Stewart discovered that the larvae evidently had made their way to the liver and lungs, but were not present in the alimentary canal, spleen, or kidneys. Another rat, killed 10 days after the first inoculation, contained many larvae in the lungs, but none in any of the other organs examined. One of the surviving rats which had completely recovered 12 days after exposure was autopsied 4 days later. The host had freed itself entirely of larvae, so far as could be determined by the examination of the various organs in the abdominal and thoracic cavities. Stewart repeated these experiments with other rats and a mouse and obtained similar results. He concluded, therefore, that in the intestine of rats and mice only a few of the larvae that escaped from the egg shells were eliminated to the outside, but that most of them were carried to the liver (pl. 2, fig. 1) and lungs (pl. 2, fig. 2) by the circulation, became localized in the respiratory tract for a time, and produced symptoms of pneumonia. Curiously enough, Stewart was inclined at first to the view that the larvae which left the host shortly after they had escaped from the egg shells, rather than those that invaded the tissues, might be the starting point of human infections by being transferred to the mouth with food or water that had become contaminated with the feces of infected rats or mice.

After confirming and extending his early experiments, Stewart traced the migratory path of the larvae through the bloodstream from the intestine to the liver and thence to the lungs. He determined that by upward migration in the respiratory tract, the larvae reached the trachea, pharynx, and buccal cavity, and were then swallowed for the second time. Now they migrated downward through the esophagus to the stomach and intestines, and tended to accumulate in the cecum. They finally passed out with the feces 10 or 12 days after inoculation.

Stewart next turned his attention from experiments with rodents to experiments with pigs. He objected to experimenting with human

beings, and wondered why those before him had neglected the obvious pig-*Ascaris* relationship as an experimental tool. By using both the human and porcine strains of *Ascaris*, he inoculated pigs and ascertained that the hepatic-pulmonary developmental cycle in this host was no different from that in rodents. Contrary to his expectations, he failed to observe development of *Ascaris* in the pig's intestine to any significant extent. Stewart was unable to account for the exit of the larval worms of the pig *Ascaris* from its accustomed host only a few days after completing the journey through the liver and lungs—a behavior not essentially different from that he had seen in rodents. He thought of the possibility that either *Ascaris* might undergo a direct development in the intestine, once it had returned there after completing the hepatic-pulmonary cycle, or that the rat and mouse might be intermediate hosts.

EXPERIMENTAL DEMONSTRATION OF DEVELOPMENTAL CYCLE IN ANIMALS

Ransom and Foster (18), whose investigations on the life cycle of *Ascaris* followed on the heels of Stewart's discoveries in 1916, rejected the view that rats and mice were involved in any way in the developmental cycle of the pig or human *Ascaris*. They regarded the hepatic-pulmonary migratory cycle as part of the normal developmental pattern of the worm in a one-host system, even though they themselves had had no better success than did Stewart in demonstrating a direct development of the helminth in the pig. As a matter of fact, the first entirely convincing experimental proof of a direct development of the pig *Ascaris* was supplied by Ransom and Foster in experiments with sheep and goats, two rather unusual hosts for this parasite. In an autopsy on a kid 28 days after the first, and 11 days after the second inoculation with the swine *Ascaris* eggs, they found numerous larvae in the lungs, trachea, pharynx, esophagus, rumen, and abomasum, and larger and more numerous worms in the intestine. The worms in the intestine, almost a centimeter long, had developed presumably, from the first feeding, 4 weeks earlier, whereas the migrating larvae had apparently developed from eggs of the second feeding, about 2½ weeks later. The localization of the larvae in the organs aforementioned showed very clearly the path they had traversed before reaching the animal's intestine. From a lamb autopsied about 3½ months after a similar inoculation with pig *Ascaris* eggs, they recovered from the intestine 50 partially grown worms, 10 to 15 cm. long. Considering the fact that sheep are rarely affected by the swine *Ascaris*, and that only one worm or a few at most, usually stunted in growth, have been observed in these aberrant hosts, the presence of 50 worms in a lamb that had been experimentally inoculated with the eggs may be considered conclusive proof of a direct development from the egg to a state approaching maturity.

MIGRATION OF ASCARIS LARVAE IN MAN

The most conclusive proof of the migration of *Ascaris* larvae in the human host was furnished by Koino (10) in Japan in 1922. Koino was familiar with Stewart's investigations and with those of one of his own countrymen, Yoshida (27), who, in 1919, had confirmed Stewart's work on the migration of *Ascaris* larvae in rodents, and infected himself by swallowing some of these larvae that had gotten as far as the lungs. After experimenting with rats and mice, Koino became interested in determining whether the symptomatology associated with the hepatic-pulmonary migration of *Ascaris* larvae in man would be similar to that which he had seen in rodents. He therefore subjected himself, and his younger brother, aged 21, to an experimental inoculation with *Ascaris* eggs. It was a fortunate coincidence that he fed the embryonated eggs of the pig *Ascaris* to his brother, and that he swallowed the eggs of the human *Ascaris*. The results he obtained supplied much-needed information on the biological difference of the worms from the two hosts.

Koino inoculated his brother with 500 pig *Ascaris* eggs. This was followed by a slight rise in his body temperature by the third day; from then to the eighth day his brother's temperature was subnormal in the morning and normal or somewhat elevated in the evening. By the ninth day it had risen to 39° C. (102° F.); the fever continued during the next 3 days and then the temperature came down to normal. Along with the fever the patient developed a cough, which gradually increased in severity, and he brought up a watery, non-sanguineous mucus. He also experienced pains in the chest and had rales all over the chest. Eight days after their onset, the symptoms disappeared and the patient recovered. No evidence of liver involvement was discovered by physical examination. No larvae were found in his sputum.

Koino himself swallowed 2,000 human *Ascaris* eggs in order, as he stated, to ascertain whether the symptoms observed in his brother were actually caused by the migration of the parasites. Like his brother, Koino developed a slight fever on the third day and reached a temperature of 39.8° C. (103.6° F.) the next day. By the ninth day after the onset of fever his temperature had returned to normal but had attained 40.2° C. (105.3° F.) before it began to subside. Along with the fever he had chills, a severe headache, and increased respiration and pulse rates, and on the fifth and sixth days after the onset of symptoms he experienced very severe respiratory difficulty, and his face became cyanotic. The number of respirations reached 56 to 58 per minute, then began to decrease along with the lowering of the temperature. By the 9th day the respiration rate was down to 24 per minute, and by the 16th day it was normal. His pulse rate

reached 90 to 120 per minute, and from the fifth to the sixth days it was very weak and thready. The cough, which had appeared, increased with the rise in temperature, but subsided on the 11th day after the onset of symptoms. His sputum increased in quantity, and on the fifth and sixth days it was tinged with blood. Perhaps one of the most interesting and biologically important findings was his discovery of *Ascaris* larvae in his sputum, despite the fact that he was seriously ill at the time the larvae became abundant there. The larvae first appeared on the third day and their number increased very sharply by the fifth day, when he counted 178 worms in 155 cc. of sputum. At this time his condition became so serious that he had to interrupt the collection of sputum for 2 days. By the 8th day the number of larvae in the sputum decreased to 16 and continued to decrease until none was found by the 11th day. The total number of larvae that he was able to count in the sputum was 212. Unlike what he observed in his brother, his liver was palpable the fourth day. It retained its enlarged size until the 10th day, and 2 days later it was scarcely palpable.

Fifty days after experimental inoculation, each of these human volunteers received an anthelmintic. Koino's brother, who had been inoculated with pig *Ascaris* eggs, eliminated no worms following this medication. Koino himself passed 667 worms, 3 to 8 cm. long. The experimenter concluded that both the human and pigs strains of *Ascaris* migrate after hatching, reach the lungs, and produce symptoms of pneumonia.

It is evident from the foregoing account that the pulmonary and other symptoms observed by Koino were due to the invasion of the liver and lungs by the migrating larvae. The onset of the symptoms, the time when they attained a high degree of severity, and the time of their remission are in harmony with the known facts regarding the invasion of and accumulation of larvae in the liver and lungs, and their exit from the respiratory tract in small mammals used in laboratory experiments, in pigs, and in other mammals. The fact that Koino's brother, unlike Koino himself, passed no worms following anthelmintic medication, despite the fact that the eggs he ingested evidently hatched and the larvae followed their usual migratory path in his body, is in harmony with the knowledge that the hepatic-pulmonary development of the human and pig *Ascaris* and of related species involves no host specificity but can take place in almost any mammal.

BIOLOGICAL DIFFERENTIATION OF HUMAN AND PIG ASCARIS

Koino's experiments afford evidence in favor of the view that the human and pig *Ascaris* are biologically distinct, despite the fact that

the two strains show no constant morphological differences. The distinction of the two strains on the basis of their host relationship has since been supported by the outcome of other experiments, especially those involving the feeding to pigs of the embryonated eggs of *A. lumbricoides*, and by epidemiological studies in the American Tropics and elsewhere. For instance, Payne, Ackert, and Hartman (17) were unable in 1925 to find a correlation between the incidence of *Ascaris* in the pig and man in Trinidad. Despite the close contacts between these two hosts and the opportunities for the acquisition of the human *Ascaris* by pigs, the incidence in these domestic animals was only about one-seventh of that in man. I made similar observations (21, 22) 3 years earlier in the Philippines. It should be borne in mind, however, that pig *Ascaris* eggs usually are abundant on the premises where these host animals are raised and over which they roam. These eggs are, therefore, a potential human health hazard, especially to children, even though they may not be able to grow up to maturity in the intestines of the human host.

The available evidence from the numerous experiments that have been performed since those that have just been reviewed has established conclusively the fact that *A. lumbricoides* develops in man direct from the embryonated egg to the adult worm. The counterpart of this helminth in the pig, to which the name *Ascaris suum* has been applied for convenience, if for no other reason, also has been shown to have an identical direct development in the pig. Moreover, the evidence at hand supports, on the whole, Koino's conclusion that the human intestine is an unsuitable habitat for the development of the pig *Ascaris* to maturity or to a stage approaching maturity. The converse also is true, because the available experimental data indicate that the pig's intestine is an unsuitable habitat for the development of the human *Ascaris*. Moreover, the epidemiological evidence collected in the United States, in the American Tropics, and elsewhere certainly does not support, as previously stated, the idea of a transfer of the human or porcine strain of *Ascaris* to the heterologous host, except to the extent that the larvae of either strain can undergo the hepatic-pulmonary migrations in either host.

It is perhaps idle even to speculate on whether man acquired *Ascaris* from the pig, or vice versa. Members of the zoological family Ascaridae parasitize mammals, such as cattle, horses, pigs, dogs, cats, and species of wild carnivores. *Ascaris* is not known to have a special attachment to primates, man's nearest zoological relatives. Man's helminth parasites are, by and large, closely related to, and in some cases identical with, those of the animals he domesticated, and of those that have invaded his home as unbidden guests. It is probably more logical to assume, therefore, that *Ascaris* was donated to man by the pig than to accept the converse of this proposition.

DISCUSSION

From the foregoing account it is clear that the knowledge we have concerning *A. lumbricoides* has been accumulated slowly and patiently over a period perhaps as long as the history of man's civilization. If little was added in 2,000 years or more to what was already known to Hippocrates about 400 B.C. or earlier, and to Aristotle several decades later, it was because of the veil of superstition and ignorance that hung over men's minds throughout the Middle Ages. The clouds that dimmed the spirit of inquiry into living phenomena were somewhat lifted by the pioneering discoveries of Redi in the 17th century on the propagation of insects. It took almost two additional centuries, however, before medical and other biological investigators began to approach experimentally the problem of the mode and course of infection with this parasite. By this approach they gradually brought to light one fact after another, sometimes in rapid succession, so that toward the middle of the 19th century, and during the ensuing two or three decades, much was discovered about how *Ascaris* spreads from one host to another. It remained for the researches that were carried out during the second, third, and fourth decades of this century to bring to light the unexpected mechanism of infection with a parasite that has been so intimately associated with man throughout the ages, and still is widespread practically the world over.

In attempts to unravel the life cycle of *Ascaris*, a number of investigators resorted to experimental inoculation of human beings, including children. Subjecting children to experimental inoculation with worms is a hazardous venture under any circumstances, and especially when *Ascaris* eggs constitute the inoculum. In the experiments carried out by Mosler and Lutz, pulmonary and other symptoms were observed. Aside, however, from the potential danger involved in medical experiments with human beings, the practice of using children as test animals cannot under any circumstances be justified, even though the investigators who resorted to this practice believed, in the light of knowledge then available, that little, if any, risk was involved in inoculating youngsters with a helminth that so many of them would, sooner or later, acquire anyway. It should not be forgotten, however, that not all the investigators who helped to piece together the life cycle of this parasite used only others as test hosts. Leuckart, Grassi, Calandruccio, Yoshida, Koino, and other experimenters did not hesitate to expose themselves to experimental infection with *A. lumbricoides*—an exposure that in the case of Koino, at any rate, was fraught with considerable danger to his health.

The life history of *Ascaris* resembles a two-host system that apparently has become compressed into a single host. The possible biological significance of the early migratory cycle of the larvae, which

precedes their later development in the small intestine, has given rise to considerable speculation. It is certain that there is much in the developmental history of this helminth that, on the surface, at least, appears to some investigators seemingly superfluous and difficult to explain. The exit of the larvae from, and their subsequent return to, the intestine, partly by passive movement with the blood-stream, and partly by their independent movements, have been regarded by some helminthologists, especially by Fülleborn (4, 5), as a probable recapitulation of the evolutionary history of these worms. Fortunately, however, the discoveries pertaining to the life cycle of *Ascaris* have opened up, in addition to these interesting speculations, new vistas so far as concerns the immunology of this worm infection. Possibly one of these is the host's vigorous defense reaction following the penetration of the larvae into abdominal and thoracic organs. This defense reaction might be responsible for the difficulties that so many investigators have experienced in attempting to rear these helminths from the embryonated egg to the adult worm in the natural hosts. Evidently, not all the problems relating to *Ascaris* infection have been entirely solved. What has been uncovered in recent years has opened the door a little wider, so as to permit further exploration of what still remains undisclosed.

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The Protection of Fauna in the U.S.S.R.¹

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THE PROTECTION of nature in the U.S.S.R., and particularly of the fauna, is a problem as vast as it is complicated. The solution of this problem requires extensive and varied measures. This article will deal only with those affecting vertebrates. In our country, with its immense area and abundant and varied natural resources (there are 300 species of mammals, 700 of birds, 161 of reptiles and amphibians, and 1,500 of fishes and cyclostomata), interest in the fauna dates back to ancient times. It was hunting that occupied the attention of our ancestors. This is quite understandable, for in the Middle Ages hunting played an important part of the daily life. This does not mean that today hunting as a sport and an industry, as a way of coming to understand nature, has lost its value.

In the principality of Kiev, and later in the Grand Duchy of Muscovy in old Russia, the exploitation and, thus, the protection of the fauna formed a branch of governmental administration. This administrative activity developed with the Russian penetration into Siberia in the 16th, 17th, and 18th centuries. The establishment of a government monopoly on fur trapping and fur trading required measures guaranteeing to a certain point the protection of fur-bearing animals.

The oldest documents pertaining to the control of hunting date from the 11th century; it is the collection of laws known as the "Rus-skaya Pravda." We must realize that in Russia hunting has never been reserved as an entertainment or a privilege for the nobility or

¹ Reprinted by permission from *Atlantic Naturalist*, vol. 14, No. 1, January-March 1959.

² Translator's note: This is a free translation of a talk given by Professor Dementiev at the Sixth Technical Meeting of the International Union for the Conservation of Nature and Natural Resources at Edinburgh, Scotland, on June 26, 1956. It was published in French in the *Proceedings and Papers* of the meeting, London, 1957. Professor Dementiev is a leading Soviet ornithologist and conservationist, professor at the University of Moscow, chairman of the Commission for the Protection of Nature of the Academy of Sciences of the U.S.S.R., and a corresponding fellow of the American Ornithologists' Union.

I am indebted to Professor Dementiev and to the International Union for the Conservation of Nature and Natural Resources for their consent to this presentation of the article.

for the state. But in another sense, the state has always been greatly interested in hunting and trapping and their produce. The control of the capture of birds for falconry (these birds, especially gyrfalcons, were also, as in Iceland, the objects of diplomatic negotiations) and the strict control of fur trapping in Siberia (called "Yassak," meaning "a tribute paid in furs") are examples of this interest. All these measures have contributed toward regulations of a conservationist nature and toward limitations on hunting. It was in this manner that the first natural reserves were organized in Russia, such as the Seven Isles, which lie to the north of the Murmansk coast. This reserve was founded in the 17th century in order to protect the eyries of gyrfalcons. Mention should also be made of the forest sanctuary of Bialovez, which dates from the 16th century. The number of Siberian furs that had to be furnished to Moscow was also controlled. On the frontiers of the Grand Duchy of Muscovy in the 16th century there were organized forest preserves called "Zasseki" (forests used for defensive purposes). Under Tsar Peter the Great, oak forests in European Russia were also protected, except against the needs of Russian naval forces. The protection of the European bison—already in practice because of the hunting interests of the Grand Dukes of Lithuania—was established as early as 1541. It was in the 18th century that many "Zakazniki," reserves for the protection of game animals, both mammals and birds, were organized. The trapping of beavers was strictly controlled and was forbidden in northern Russia by the 18th century. In the same century no hunting was allowed in the districts of St. Petersburg and Moscow (to the advantage of the hunting of the Imperial Court, though their sport was erratic and rather infrequent).

From this we may conclude that the history of the protection of game dates far back. We have only given fragments here. It is necessary to add that in the areas where hunting was largely carried on by the natives (Siberia, Turkestan), these people had always given attention to the conservation of game. These animals served not only as the objects of sport, but as a means of subsistence. In these regions many localities were considered, by tradition, as sanctuaries.

The situation by 1917 was not at all reassuring. The hunting law of 1892, which was in effect at this time, considered only the interests of the large landowners; the questions of hunting in the north, in Siberia, and in Turkestan were not being considered seriously. It was only in 1912, 1913, and 1916 that measures were taken for the protection of the sable (*Martes zibellina*) in Siberia, when the numbers of this valuable animal were diminished to a dangerously low point.

It should be mentioned that already in the 18th century the law of June 17, 1763, forbade all hunting in Russia between the 1st of

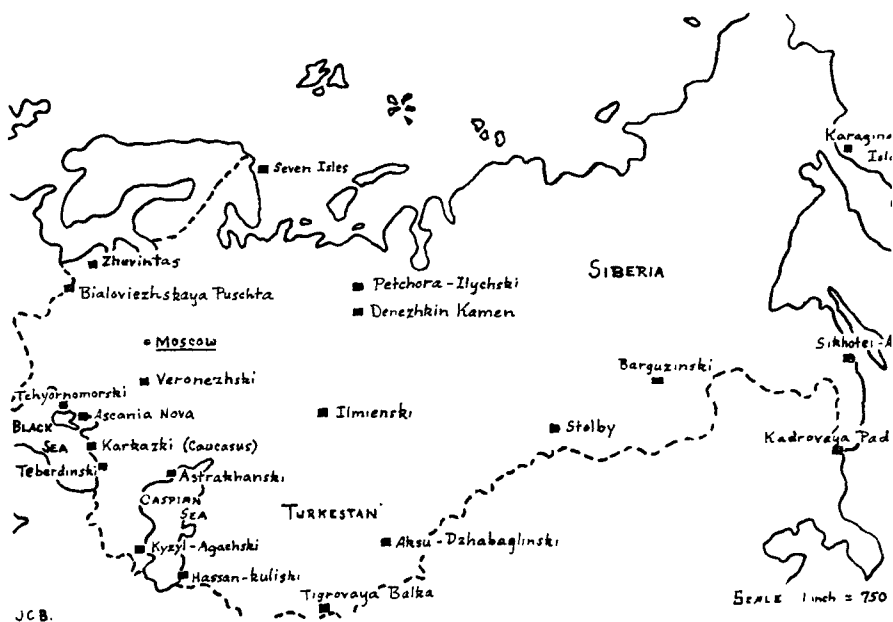


FIGURE 1.—The U.S.S.R., showing areas cited.

March and the 29th of June (Julian calendar)—certainly a progressive measure.

At that time hunting success was considered from only one point of view—the quantity of animals taken. The increase of population, the perfection of hunting arms, the steadily rising prices for game—all this, seen from the economic angle, caused the intensification of hunting as an industry (and as a sport).

The negative influence of human activity in our country increased toward the end of the 19th century and the beginning of the 20th. Its chief victims were the sea otter (*Enhydra lutris*), the northern fur seal (*Callorhinus ursinus*), the sable, the European moose (*Alces alces*), etc. The statistics are incomplete, but the facts themselves cannot be doubted.

The Soviet Government in 1917 had to face altogether new problems in the field of conservation and the exploitation of nature. The fundamental social changes, the suppression of large estates, and the nationalization of the land necessitated the founding of a completely new system, both scientific and rational, of exploitation of natural resources. New methods for the conservation of nature were especially necessary. The general characteristics of this system follow.

The protection of nature is thought of as an important social problem of scientific, moral, esthetic, and economic character. The solution of this problem certainly has great value to the present generation, as well as to those of the future. Therefore, the protection of

nature should aim at the conservation, the enlarging, and the multiplication of natural resources, not made by man, for man's own use. The basis of this protection is an organized and active intervention by man in the natural processes, and, as much as possible, in their regulation. The "passive conservationist" theory appears altogether insufficient.

Such active methods of nature protection must be founded on scientific research. Correct solution of the questions of nature protection depends above all upon ecological, both zoological and botanical, research. It is evident that the problems of numerical fluctuations of populations, of fertility, of reproduction, of the influence on these processes of changes in the natural surroundings, research on seasonal distribution and on migrations, on geographical and biotical distributions, all have a basic and essential value in the solution of protection problems. Research in the areas mentioned above is made by many of the institutions of the Academy of Sciences of the U.S.S.R., the academies of sciences in the various republics, and by specialized scientific universities and institutions—for example, the national park system. The activity in this field by the Russian Society for the Protection of Nature, founded in 1924, should certainly be mentioned.

Ecological questions are treated in hundreds of publications which have served as a basis for practical solution of fauna protection problems in the U.S.S.R. We should note several national park publications on these subjects: research on the sable by Raevski et al.; those on the tiger and the moose by Kaplanov; those on the wintering of birds on the southeastern and southwestern coasts of the Caspian Sea; those by Nasimovitch on the hoofed animals of the Caucasus region, those by Dmitriev on the hoofed animals of the Altai region; research on faunal changes since the construction of artificial reservoirs in the Volga system; Zablotski's work on the European bison; a whole series of publications on the beaver and the moose, etc. A bibliography of these works was published in 1948 and in 1949 by Nasimovitch. There is a special institute which studies the symptoms of fluctuations in game populations. It is from these studies that plans are made for the annual exploitation of the principal species. Thus, the principles and the perspectives of conservation are always taken into consideration in the planning of the use of natural resources: water and forests, fish, birds, mammals, etc. We have always tried to consider the natural renewal and growth of these resources.

As much as possible is done to improve living conditions of the fauna. For example: the prohibition of water pollution by hydrocarbonates and by waste from chemical plants; the prohibition of water pollution caused by discharge from breweries; new forest ranges and a strictly regulated system of forest exploitation; and the

greatest possible improvement of habitat, especially in relation to nutrition and feeding.

Finally, the fauna is being actively enriched through introduction and reintroduction. Animal species new to the fauna of the U.S.S.R. are brought in, and species with a low population or of local distribution are increased and dispersed. Acclimatization ranges from the protection of birdlife by means of artificial nesting sites to the introduction of new types of food for fish.

Special prohibitive measures are used in animal protection. Game animals that are low in numbers may be taken only in limited and fixed quantities with a special permit. For many species, complete protection has been established for a specific period.

Finally, absolute protection is maintained in some cases. This includes the national park system on one hand, the absolute prohibition of the capture of certain animals on the other.

Such are the general principles of fauna protection in the U.S.S.R.

Various organizations administer nature protection in the U.S.S.R. The protection of our waters and fish depends upon the Management of Water and Fish of the Ministry of Fisheries and its subordinate services. Problems of water and air pollution are regulated by the General Sanitary Survey and by the local inspections of the Ministry of Health. Hunting is controlled by the Management of National Parks and Hunting of the Ministry of Agriculture, by the Managements of National Parks and Hunting in connection with the councils of ministers of the Soviet republics, and their local representatives. The protection of our forests is carried out by the General Management of Forests of the Ministry of Agriculture. The "dead" resources are protected by the Ministry of Geology. For the solution of scientific problems of nature protection, for the coordination of activities in this field, the Academy of Sciences of the U.S.S.R. established a special committee in March 1955, composed of members of the Academy and other scientists, as well as representatives of interested official institutions. Similar committees were created by the Academies of Sciences of the majority of the Soviet republics.

Education in nature protection is carried on by schools and by young naturalists' groups (for example in the form of "bird days," "forest weeks," etc.), as well as by societies for nature protection. The oldest among these societies, the Russian Society for the Protection of Nature, was started in 1924. It now includes provincial affiliates. This group has contributed greatly to the solution of many questions of nature conservation. Other scientific societies (the Geographical Society of the U.S.S.R., the Moscow Naturalists' Society) participate also in work having nature protection as its goal.

Finally, the system is carried on by the activity of numerous hunt-

ers, working as inspectors and as voluntary aides, and by the forest wardens.

And now a few examples showing the realization of the principles just mentioned.

We shall omit here the activity of the national parks, and discuss other aspects of the protection of fauna in the Russian Republic. By federal control, the following species of mammals benefit through protection in all parts of the Republic: The sable, the otter, martens, the Russian desman (*Desmana moschata*), the Ussuri dog (*Nyctereutes procyonoides*), the sea otter, the northern fur seal (*Callorhinus ursinus*), the beaver, all species of deer (the roebuck excepted), the moose, the saiga antelope, the European bison, the goral (*Nemorhaedus goral*, antelope-goat). Protection is absolute for the following species: The goral, the beaver, the sea otter, the European red deer, the Axis deer, and the European bison. Other species—their numbers having increased very much during recent years—may be hunted in limited numbers by persons duly sanctioned and possessing special hunting permits, indicating the number, the dates, and the other conditions of the hunting of these animals. This system was begun in 1946, and included a severe limitation on the hunting of protected animals. It had been adopted for the moose in 1945. The hunting of moose, an animal which had become rare, was completely forbidden in 1919. The results of this protection were so satisfying that now the moose has become quite common, not only in Siberia, but also in the European section of our country (for example, the immediate environs of Moscow).

In reality the list of protected species is much longer, because hunting controls imposed by local authorities (the executive committees of the Soviets of the Oblasts and of the Krai, the councils of ministers of the Autonomous Soviet Republics) give complete protection for animals that have become rare or endemic or important scientifically in the region of their jurisdiction. It is thus that in Russia, which includes 62 large administrative areas, the roebuck is protected in 34 areas, the silver fox in 27, the weasel in 26, the mink in 23, the badger in 20, the ermine and the ferret in 15, the reindeer in 13, the wild boar in 13, the steppe marmot in 12, the European red deer in 9, the Siberian red deer (*Cervus xanthopygus*) in 7, the brown bear in 5, the bighorn sheep (*Ovis nivicola*) and the ibex in 4, the Corsak fox (*Vulpes corsac*) in 4, the Persian gazelle (*Antelope subgutturosa*) in 2, the tiger in 2, the chamois in 2, the leopard in 1, etc. The total number of mammals protected by local authorities in the Russian Republic is now 40. We must realize that for many of these species this local protection covers their whole area of distribution in the U.S.S.R.: for example, such is the case of the chamois, the red deer,

the bighorn sheep (*Ovis nivicola*), the ibex, the Persian gazelle (*Antelope subgutturosa*), and the tiger.

The planned use of natural resources in the U.S.S.R. is essentially based upon the principle that all mammals, birds, fishes, etc., constituting the fauna are a form of national wealth. All reduction of animal populations must be legally performed: whether it is hunting for sport or for commercial gain, or whether it is part of the battle against injurious animals in terms of agriculture, silviculture, and epidemiology. Aside from this, Soviet legislation considers the fauna from a purely conservationist point of view. This is why, for example, the destruction of nests and eggs of birds, the hunting of female hoofed mammals and their young (at the age of 1 year and under), and the destruction of mammal burrows and dens (wolves and injurious rodents excepted) are absolutely forbidden.

The law on hunting based on the above principles was put into effect in Soviet Russia in 1920; since then it has been enlarged and amended many times. These laws, as well as decrees by local authorities, control the list of species that may be hunted, the dates, and the methods of hunting, etc.

We must not forget that the establishment of a state monopoly on fur bearers makes impossible any commerce of game products having illegal origin.

The same principle concerning the limitation of hunting licenses was applied to the hunting of the saiga antelope (*Saiga tatarica*). At the beginning of this century this animal was almost extinct. Complete protection was established in 1920, and now, according to a census, there are on the steppes of Astrakhan, of Stalingrad, of Stavropol, and of Grozny some 230,000 individuals of this species. This antelope has also become very numerous in Kazakhstan. The number of desmans, completely protected between 1935 and 1939, has grown enough to permit a limited exploitation of this animal.

Turning to birdlife, complete protection established by the federal government includes such species as the flamingo, the egrets, and several other groups—passerines (crows excepted), woodpeckers, cuckoos, etc.

The same situation of additional control by local authorities protects a large number of other birds—the swans in 40 regions, the Hungarian or gray partridge in 28, buteo-type hawks in 23, the European kestrel in 22, owls (the eagle owl, the snowy owl, the scops owl, the short-eared owl excepted) in 21, the bustard in 19, harriers (the marsh harrier excepted) in 18, the black grouse in 17, the little bustard and the pheasant in 10, the steppe eagle in 7, the ptarmigan in 7, the larger falcons and the white stork in 3, the Siberian spruce grouse (*Falci-pennis falcipennis*) in 2, the Caucasian black grouse in 1, the rhinoceros auklet (*Cerorhinca monocerata*) and the Ross gull in 1, etc.

Recently the government of the Russian Republic made an important step in the protection of Arctic fauna (the polar bear, the reindeer, and the colonies of sea birds).

Hunting methods that might exterminate animals en masse are forbidden everywhere. These include hunting from an automobile or from an airplane, the use of devices for the capture of large numbers of birds at a time, and the capture of animals that are incapable of defense—molting geese, etc. Hunting birds in the spring is forbidden in many areas, including the Russian Federated Republic and the Ukraine. Some other republics protect wintering birds along the shores of the Caspian Sea (Azerbaijan, Turkmenistan).

Fish protection is carried out primarily by careful control of fishing (dates, gear, safeguards for fish not of legal size, etc.), by local protection—controlling water systems and certain species; and, finally, by a series of measures designed to bring about the best possible reproduction of fish. The battle against water pollution also enters the picture here.

As I have already mentioned, the system of fauna protection is essentially made up of the conservation and improvement of conditions in the natural surroundings. For example, the forests, with their multiple value taken into consideration (the conservation of water sources, the protection afforded cultivated land, commercial use, etc.), are divided into three categories: (1) Forest sanctuaries, national parks, forests protecting river sources, and cultivated areas, and forests around cities and industrial centers as well as the woods of the Siberian steppes; all these are strictly protected and carefully cultivated. (2) Forests that undergo very limited exploitation, with scientific reforestation. (3) Forests far from centers of population and from industrial centers, situated to the north and northeast of the country in European Russia and in Siberia; they are more fully exploited following previously established plans. The division of forests into categories is based upon scientific knowledge with the aim of conserving the timber resources of the U.S.S.R. The importance of this system in problems of fauna conservation is evident.

Finally, some words on the introduction and the reintroduction of animals, seen from the point of view of conservation and the protection of nature. The history of such projects before 1917 is not long.

Toward the middle of the 17th century, there were attempts to introduce the Siberian silver fox into the woods of the Moscow region. G. Steller in 1751 suggested the introduction of the sea otter outside of its natural range. In 1886 five beavers from White Russia were taken to Ramon, in the governmental district of Voronezh; already by 1901 and 1907 surplus beavers from Ramon were introduced to new areas. In 1892 seven wild rabbits were introduced near Kherson, on

the Dnieper River; this animal is now common in the Ukraine between the Dnieper and the Dniester Rivers. In 1901 five sables were transported to Karaginski Island in the northeastern part of the Kamchatka Peninsula; in 15 years they became common. The fallow deer was introduced in many places in European Russia. The mouflon was brought into the Crimea, as were European bison. In the Askanya Nova Park, bison were introduced (unfortunately they crossed with the gray race of Ukrainian bulls), along with many African and Asiatic antelopes. There was an effort to introduce pheasants, and also ostriches and emus; attempts were made in many localities to introduce the Hungarian or gray partridge; the francolins were introduced in Turkmenia, the red-legged partridge in the Crimea, etc. In 1857, on the initiative of Prof. A. Bogdanov, a committee on animal and plant introduction was founded at Moscow; it was reorganized in 1863 as the Society of Introduction. (At present the introduction of land animals is done mostly under the auspices of the Institute of Hunting as well as under the national parks.)

But, taken as a whole, introduction before the October Revolution (1917) was only accidental or experimental. It was only after 1917 that the introduction and reintroduction of animals were undertaken on a large scale.

The theoretic preparations for these activities, in regard to fur bearers, were started in 1925, under the direction of Professor B. Zhitkov. The realization of these plans came in 1927 with the introduction of the muskrat (*Ondatra zibethica*). Since then and until 1953 (N. Lavrov, 1954), this rodent, numbering 117,000 individuals, was introduced in 500 localities throughout the U.S.S.R. It already occupies an important place in the fur industry of our country. In 1930 another rodent, the nutria (*Myopotamus coypus*), was brought into Caucasia and Turkestan. In many regions the American raccoon was introduced, as was, in great quantity, the American mink (*Mustela vison*). The Ussuri dog (*Nycthereutes procyonoides*) was introduced in European Russia and the Transcaucasia. The sable was reintroduced in Siberia with great success; since then the numbers of this precious animal have grown to a considerable total. A great deal of work has been done on the introduction of beavers in European Russia and in Siberia, and this animal now inhabits nearly 50 administrative areas in our country. The squirrel of central Siberia, the "teleoutka," an animal with an excellent pelt, was introduced in the Crimea and the Caucasus. But in a short time this animal lost its remarkable fur qualities, making the economic success of this introduction not very satisfactory. From the point of view of evolutionary theory the results will no doubt be very interesting. The European hare (*Lepus europaeus*) was brought into Siberia. In many national parks of

Russia and Transcaucasia, the Axis deer (*Cervus nippon*) has been introduced. There have been attempts to populate the Caucasus with Siberian marmots. The same work has been done with certain birds—the pheasant, the capercaillie, the hazel hen, the Hungarian or gray partridge, the rock partridge, the ptarmigan, and the black grouse.

Attempts to increase and reintroduce the European bison should also be mentioned. It was well known that this species, with its unequaled scientific and historic value, was in a most precarious position after the two World Wars. Now, pureblooded European bison are well taken care of and have multiplied extremely well in our national parks of Bialovezh and of Oka (Serpukov district, in the region of Moscow). A large number of hybrid bison (but of nearly pure blood) live in the national park of the Northwest Caucasus.

These are only a few examples of work undertaken by the U.S.S.R. in introduction and reintroduction.

For birds, we are proceeding on a large scale with measures for their protection, for the improvement of nesting conditions, etc. There have been several attempts to import the eggs and young of insectivorous species to new tree farms, as well as measures to establish mallards and bean geese (*Anser anser*) on certain water systems.

Fishes have also been introduced. We can cite the very successful introduction of the mullet (*Mugil cephalus*) in the Caspian Sea, undertaken in 1934; that of the sturgeon (*Acipenser nudiventris*) in the Aral Sea between 1934 and 1952; the bringing of the trout (*Salmo ischan*) from Lake Sevan in Armenia to Lake Onega (near Leningrad); the introduction of the lavaret (*Coregonus lavaretus*, a whitefish of central Europe) in many lakes of European Russia; that of topminnows (*Gambusia affinis*) in many localities to control malarial disease; attempts to introduce in various lakes the sturgeon and the sterlet (another, but smaller, sturgeon, *Acipenser ruthenus*). Finally, there have been attempts to improve feeding conditions for the sturgeons of the Caspian Sea by introducing nereid worms.

Thus, we see that results already obtained in the domain of nature protection in the U.S.S.R. are encouraging. But there can be no doubt that there is much yet to do. We must remember that besides the ecological studies to be intensified, besides the official organization that must be unified and enlarged, besides the strict application of the law, game regulations are being abused and habitats necessarily undergo many changes. Widespread understanding of the concepts of nature conservation must be developed, especially among the new generation, in both primary and secondary schools (already in many of our universities there are courses dealing with nature protection).

Finally, it must be said that the solution of many problems—and not the least important ones—concerned with the protection of the

nature and with the fauna of the U.S.S.R. needs international co-operation; for example, the protection of aquatic mammals and migratory birds. As far as we know, the birds using the great Caspian flyway, protected in the U.S.S.R. by three special refuges—Astrakhan, Kyzyl-Agatch, and Hassan-kuli—should definitely be protected along the southern coastal areas of the Caspian Sea. The International Committee for the Protection of Birds gives a sound means for solving this problem. The work of the International Committee for the Protection and Hunting of Whales, of which our country has been a member since 1946, represents an encouraging example. These are only a few examples.

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Reconstructing the Ancestor of Corn¹

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[With 4 plates]

OUR PURPOSE in reconstructing the ancestor of corn is to retrace, as far as possible, some of the principal steps which have been involved in its evolution under domestication. We do this in the hope of gaining a better understanding of the corn plant as one of those unique biological systems which man employs on a grand scale to convert the energy of the sun, the carbon dioxide of the air, and the minerals of the soil into food. Corn is one of perhaps not more than a dozen species of cultivated plants of worldwide importance—each one the principal source of food of millions of people—which quite literally stand between mankind and starvation.

But corn is something more than an important food plant; it is also a mystery, a fascinating botanical mystery, as challenging to a scientist as is a mountain to an employer.

A UNIQUE CEREAL

Modern corn, our starting point in this study,² is unique among the cereal grasses in the nature of its inflorescences [1, 2].³ The terminal inflorescence, commonly called the "tassel" (fig. 1, *A*, *C*), usually bears only male flowers, each of which contains three pollen sacs or anthers (fig. 1, *D*) packed tightly with some 2,500 pollen grains. These are small, about $\frac{1}{250}$ inch in diameter, light in weight, and are easily carried by the wind.

The lateral inflorescences (fig. 1, *A*, *B*), which when mature become the familiar ears of corn, have only female flowers which bear the

¹ Paper presented at the annual meeting of the American Philosophical Society, Apr. 25, 1958. Reprinted by permission of the Society from the Proceedings, vol. 102, No. 5, October 1958.

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³ Numbers in brackets indicate references at the end of text.

pollen-receptive organs commonly known as the "silks." These are covered with fine hairs and are admirably designed to capture wind-blown pollen (fig. 1, *E*). Thus corn, in contrast to the majority of cereals, is a naturally cross-pollinated plant. It is this feature which makes possible the production of hybrid corn, one of the most spectacular developments in applied biology of this century.

Each silk represents a potential kernel and must be pollinated in order for that kernel to develop. The kernels themselves are firmly attached to a rigid axis, the cob, and are not covered, as are those of other cereals, by the floral bracts which botanists call "glumes" and which the layman knows as "chaff." Instead the entire ear is enclosed, often quite tightly, by modified leaf sheaths, the husks or shucks (fig. 1, *B*). Thus, while in other cereals the kernels are protected individually, in corn they are covered en masse. The result is that cultivated corn has no mechanism for the dispersal of its seeds and hence is no longer capable of reproducing itself without man's intervention. The very characteristics which make corn so useful to man render it incapable of existing in nature, and it is probable that corn would quickly become extinct if deprived of man's protection.

How, then, did corn's wild ancestor differ from cultivated corn in ways which enabled it to exist in nature for thousands, if not millions, of years before man appeared on the scene? This is one of the questions which we hoped to answer by reconstructing the ancestral form. Our reconstruction is based in part upon fossil and archeological remains and in part upon genetic recombination of some of the primitive characteristics which still exist in modern corn varieties.

FOSSIL CORN POLLEN

The fossil evidence comprises a number of pollen grains isolated from a drill core taken from a depth of more than 200 feet below the present site of Mexico City. These were recognized as unusually large pollen grains of a grass by Paul Sears of Yale University and Kathryn Clisby of Oberlin College, who, in connection with charting climatic changes, were engaged in pollen studies of the drill core. The pollen was identified by Elso Barghoorn [3] of Harvard University as that of corn, which has the largest pollen of any known grass. Although assigned to the last interglacial period and therefore, on the basis of recent estimates, probably at least 80,000 years old, the fossil pollen is scarcely distinguishable in size, shape, and other characteristics from modern corn pollen (pl. 1, fig. 1). This fact leaves little doubt that the ancestor of corn was corn and not one of its two American relatives, teosinte or *Tripsacum*.

OLDEST CULTIVATED CORN

The oldest known remains of cultivated corn come from a once-inhabited rock shelter in New Mexico known as Bat Cave, which was excavated by Herbert Dick, of the Peabody Museum of Harvard University and later of the Colorado University Museum, in two expeditions, in 1948 and 1950 [4, 5]. This cave was inhabited for several thousand years by people who practiced a primitive form of agriculture and an even more primitive pattern of sanitation. During the centuries of their occupancy, garbage, excrement, and other debris accumulated in the cave to a depth of 6 feet, creating exactly the kind of site which archeologists delight to dig into. At the bottom of this accumulation of trash, Dick turned up some tiny cobs of ancient corn which have been dated, on the basis of Willard Libby's radiocarbon determination of associated charcoal, at about 5,600 years.

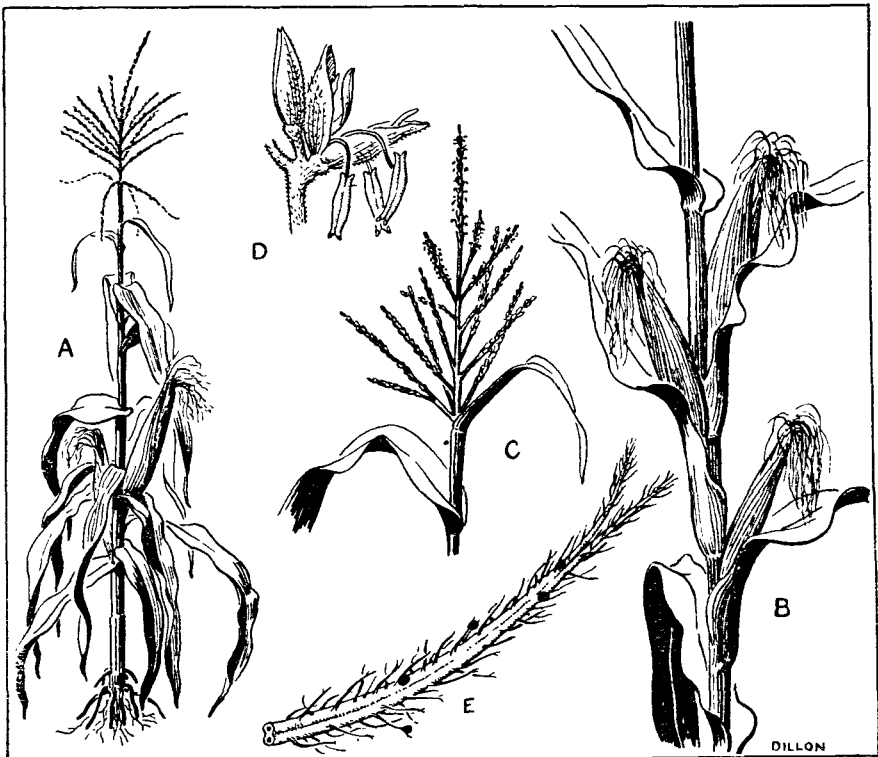


FIGURE 1.—Botanical characteristics of the modern corn plant. (A) The entire plant, showing the male inflorescence, the tassel, at the tip of the stalk and the female inflorescences, the ears, in the middle region; (B) young ears enclosed in husks with the pollen-receptive organs (the silks) protruding from the ends; (C) typical tassel; (D) typical male flower with three anthers containing pollen; (E) a single silk magnified to show hairs and adhering pollen grains. [From P. C. Mangelsdorf, "Corn" (2), by permission of *Encyclopaedia Britannica*]

Three of these ancient cobs are compared in plate 1, figure 2, with a 1-cent piece whose diameter is about equal to their length. One of the tiny specimens is compared in plate 1, figure 3, with ears of two modern races of corn: the dent corn of the U.S. corn belt and a large-seeded flour corn of Peru. How could a corn like the Bat Cave corn have evolved into these and other modern races even in 5,600 years? This is the principal question which we hoped to answer by retracing some of the steps involved in corn's evolution under domestication.

Since there were no living seeds of the Bat Cave corn it was impossible to work forward experimentally from it to modern corn. The alternative was to work backward from present-day corn by combining primitive characteristics still occurring in living varieties. But what characteristics of corn are primitive? My associate, W. C. Galinat, and I sought to determine this by an intensive study of one of the Bat Cave specimens which contained the partial remains of a single kernel. Each part of this cob was carefully dissected out and measured. On the basis of the measurements, Galinat pre-

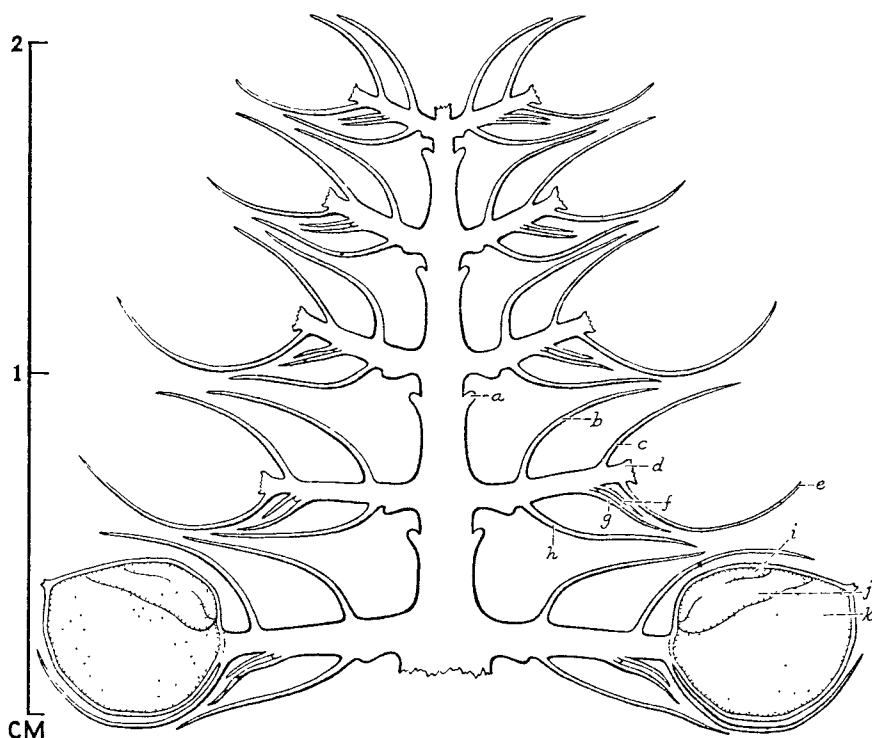


FIGURE 2.—Diagrammatic longitudinal section of one of the Bat Cave cobs, based on measurements of dissected parts. The tiny kernels show that this was a popcorn; the long pedicels on which the kernels are borne and the bracts which almost enclose them indicate that it was also a pod corn. [Drawing by W. C. Galinat]

pared the diagrammatical, longitudinal section illustrated in figure 2. The tiny kernels which this cob must once have borne could only be those of popcorn, a type in which the kernels are small and hard and capable of exploding when exposed to heat. The long stems or pedicels on which the kernels were borne and the long floral bracts which almost completely enclosed them show that the Bat Cave corn was also a form of pod corn, a type in which the individual kernels are enclosed in pods or chaff.

It is interesting to note in this connection that the late E. Lewis Sturtevant, a longtime student of corn, concluded many years ago that both popcorn and pod corn are primitive. My former colleague R. G. Reeves and I [6] later reached a similar conclusion. The ancient Bat Cave specimens provide convincing archeological evidence in support of these conclusions.

CROSSING PRIMITIVE CORNS

What we have done, then, is to cross a number of varieties of popcorn from various parts of the world with pod corn (pl. 3, fig. 2), which still occurs as a "rogue" or "freak" in some South American varieties and which in some localities is preserved by the Indians, who believe it to have magical properties. Pod corn has also sometimes been grown in gardens in the United States as a curiosity. Today it is most likely to be found in the experimental cultures of corn geneticists, who maintain it as one of the "marker" genes on the fourth long-est chromosome of corn.

There is no doubt that pod corn is primitive in its characteristic of enclosing the kernel in glumes or chaff, as do all other cereals and virtually all other grasses. Despite this fact, and because it is often monstrous and sometimes sterile, it has been dismissed by a number of botanists from any role in the ancestry of corn [7]. We believe that its monstrousness has been misunderstood—that pod corn is monstrous today only because it is a "wild" relict character superimposed upon modern highly domesticated varieties. Today's pod corn is comparable to a 1900 chassis powered by the engine of a 1958 car. The surprising thing is not that pod corn is sometimes monstrous but that it is not more so—that the particular genic locus which governs its expression is capable of functioning at all in a milieu so different from that in which it was undoubtedly well adapted. We have assumed that pod corn would be less monstrous and would exhibit normal grass characteristics when combined with other "wild" genes, and we hoped to find these in varieties of popcorn.

Our hopes have been realized. Popcorns in general tend to reduce the monstrosity of pod corn when crossed with it, and some varieties do so quite drastically. The varieties Lady Finger and Argentine

carry complexes of modifying genes which appreciably reduce the monstrosity of pod corn, and a third variety, Baby Golden, carries a major modifying gene which, on the basis of preliminary linkage tests, appears to be on the sixth chromosome and which acts as an inhibitor of pod corn, reducing its expression by approximately half.

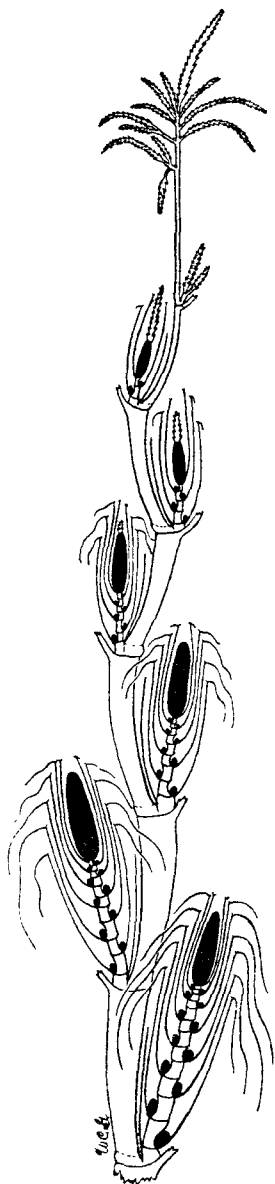


FIGURE 3.—Diagrammatic longitudinal section based on data from several plants of a many-eared corn stalk, showing how the position of the ear on the stalk affects its characteristics. The higher the ear, the smaller its size, the fewer its husks, and the more likely it is to bear both male and female flowers. [Drawing by W. C. Galinat]

By combining these modifying and inhibiting genes from several popcorn varieties with the pod-corn gene, we have developed a number of strains of popcorn which, having this gene present on both of their fourth chromosomes, breed true for the pod-corn character. Some of these homozygous strains are much less monstrous than the usual forms of pod corn, are completely fertile, and might under suitable conditions be capable of surviving in the wild.

EFFECTS OF A SINGLE GENE

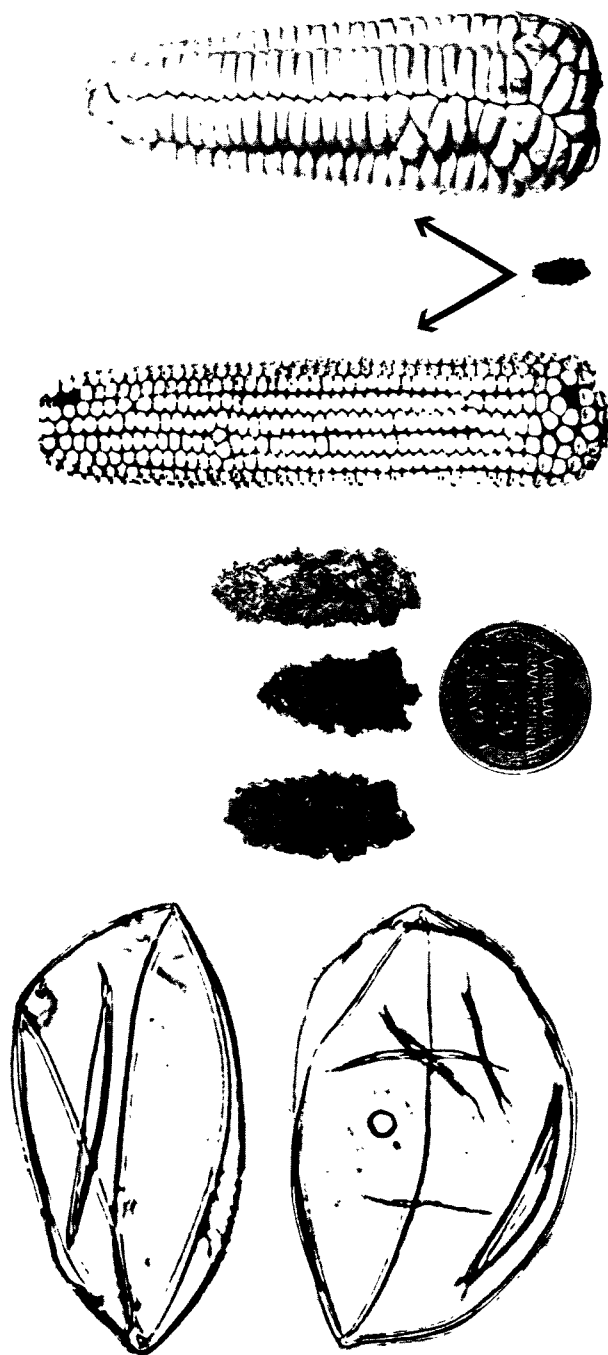
The majority of these true-breeding pod-popcorns have other characteristics which we may now regard as primitive. The plants, when grown on fertile soils, instead of having one stalk, as do most modern corns, have several (pl. 3, fig. 1), and in this respect resemble the majority of wild grasses, including all the known relatives of corn, both American and Asiatic. The plants are shorter than ordinary corn because one of the numerous effects of the pod-corn gene is to shorten and thicken the upper internodes of the stalk. This is well illustrated in plate 3, figure 1, which shows three plants of popcorn in one family: one lacking the pod-corn gene, one having the gene on one member of its fourth chromosome pair, and one having the gene on both members of the pair. There is a progressive decrease in height through this series of three genotypes resulting from a shortening of the upper internodes. This shortening causes, or at least is accompanied by, the development of a terminal inflorescence which bears both male and female flowers, the male flowers at the tips and the female flowers at the bases of the same tassel branches (pl. 2). These branches are quite brittle when mature and break apart easily when disturbed by the wind or by birds. They thus provide one of the most important primitive characteristics which cultivated corn lacks: a mechanism for the dispersal of seeds.

POSITION OF THE EAR

Plants of homozygous pod corn frequently do not have ears—most of their energy is apparently concentrated in the terminal inflorescences—but when they do have ears these are usually borne high upon the stalk (pl. 2), often at the joint of the stem immediately below the tassel. This elevation of the position of the ear has profound effects which are illustrated by the diagram in figure 3. The diagram, which is based on data from several many-eared plants, shows how a number of the characteristics of the ears are determined by their position on the stalk: (1) The higher the position, the smaller the ear, partly for the simple mechanical reason that the stalk at this position is slender and is incapable of bearing a heavy load. It would be mechanically impossible for the large modern ear of corn



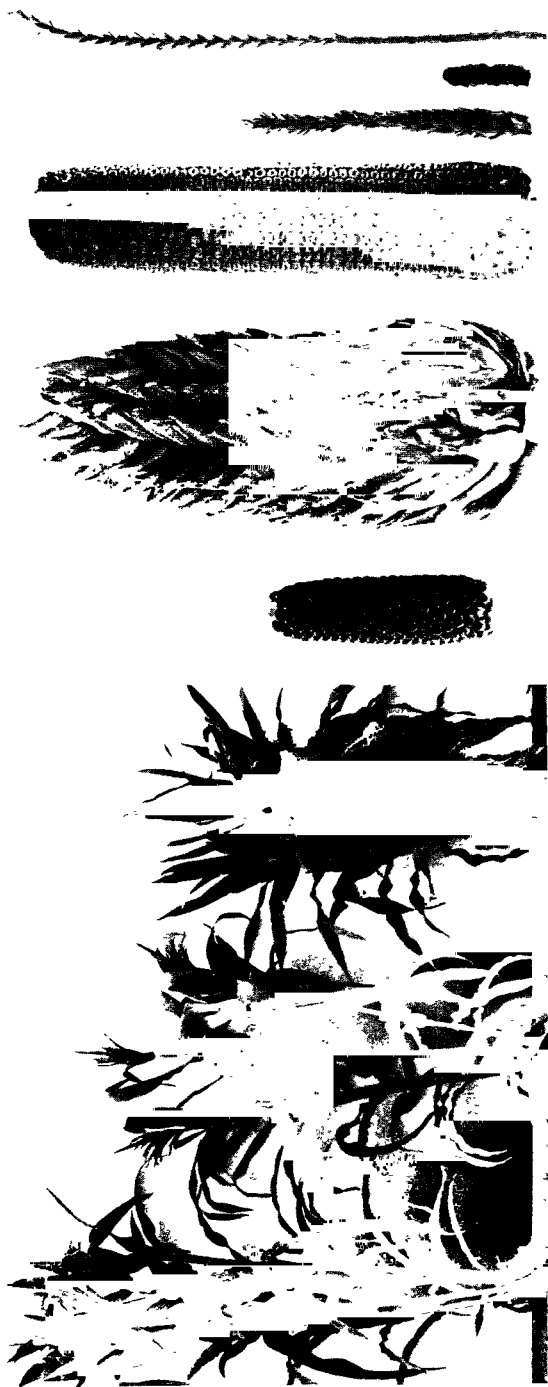
FIGURE 4.—Environmentally induced and genetically controlled variation in the corn plant. Plants (from left): (1) a plant of pod-popcorn as it might have grown in nature in a poor site in competition with other natural vegetation; (2) the same, grown under primitive agricultural conditions; (3) the same, grown in a fertile site free of competition with weeds (this plant is essentially the same as the plant at right in pl. 3, fig. 1); (4) a popcorn plant which has lost the pod-corn gene (this is the counterpart of the plant at left in pl. 3, fig. 1); (5) New England flint corn, in which human selection for larger ears has tended to eliminate the secondary stalks, reducing them to "suckers"; (6) Cornbelt dent corn, in which the trend noted for (5) has been carried still further; Cornbelt dent corn is usually single-stalked, commonly bearing a single large ear in the middle region of the stalk. The middle position of the ear has both mechanical and physiological advantages over a terminal position and probably accounts for corn's superiority over other cereals in its capacity to produce grain. [Drawing by W. C. Galinat]



FIGURES 1-3.—1, left: Fossil pollen of corn (top) from more than 200 feet below the present site of Mexico City compared with a pollen grain of modern corn (bottom) at the same magnification. In spite of some 80,000 years' difference in their ages, these two pollen grains are virtually identical in their characteristics, and they show that the ancestor of corn was corn and not one of its two American relatives, teosinte or *Tripsacum*. ($\times 445$.) (From Barghoorn et al., "Fossil Maize from the Valley of Mexico" [3].) 2, center: Three cobs of prehistoric corn from Bat Cave compared with a 1-cent piece. Radiocarbon determinations of associated charcoal date these at 5,600 years. (Actual size.) 3, right: One of the Bat Cave cobs (center) compared with a modern ear of Cornbelt dent (left) and a large-seeded Peruvian flour corn (right). Extremely rapid evolution has been involved in producing such drastic changes even in 5,600 years, the estimated difference in age.



A tassel and ear of a true-breeding pod corn. The shortening of the internodes of the upper part of the stalk causes, or is accompanied by, a tassel which bears both male and female flowers. The withered silks immediately below the tassel are from female flowers on the tassel branches which bloomed several weeks before this photograph was taken. Several seeds, resulting from pollination of these flowers, are visible. Such seeds are easily dispersed when mature by the breaking of the fragile tassel branches. The fresh silks to the left of the tassel are from a subtassel ear which is enclosed in husks when young but can emerge from them and disperse its seeds when mature. The silks of this ear can be pollinated by pollen from the anthers in the tassel of the same plant, but the female flowers in the tassel can receive pollen only from another plant. Thus, the reconstructed primitive corn plant has devices for both self- and cross-pollination.



FIGURES 1-3.—1, left: Three plants of a many-stalked popcorn differing with respect to the pod-corn gene. The first plant (left) lacks this gene; the second (center) has it on one member of the fourth chromosome pair; the third (right) has the gene on both members of the fourth chromosome pair. The progressive decrease in height is associated with the pod-corn gene, which causes, among other effects, a shortening of the internodes of the upper part of the stalk. 2, center: An ear of Argentine popcorn (left) and an ear of present-day pod corn (right). Popcorn is primitive in having small hard seeds. Pod corn is primitive in having its seeds enclosed in pods or chaff, like the other cereals. These two types were crossed in order to combine their primitive characteristics. 3, right: The reconstructed ancestor of corn, an ear of pod-popcorn (second from left) compared with a modern ear of dent corn (far left) and a prehistoric cob of La Perra Cave corn (second from right). The dent corn weighs 317 grams; the reconstructed ear has female flowers below and male flowers above and in this respect resembles a spike of *Tripsacum* (far right), a wild relative of corn. The La Perra cob also once had a male portion, which has been lost; only the stump of its stem still remains. Without its kernels and male spike, the reconstructed ear would weigh 0.87 gram—only slightly more than the La Perra cob, which weighs 0.52 gram.



Figure 1.—A prehistoric Zapotec funerary urn from Mexico with two representations of primitive corn ears in the headdress and one in the hands of the maize god.



Figure 2.—Details of one of the ears shown above. It is probable that the slender column above the small ear was intended to represent the male spike of a prehistoric ear similar in some of its characteristics to the reconstructed ancestral form illustrated in plate 3, figure 3.

to be borne near the slender tip of the stalk. (2) The higher the position, the more likely is the ear to have both male and female flowers. (3) The higher the position, the shorter the lateral branch or "shank" upon which the ear is borne. The shorter the branch, the fewer the joints from which the husks arise, the fewer the husks, and the less completely the ear is enclosed. Thus an ear borne immediately below the tassel is enclosed while the young seeds are developing, but as these mature the husks flare open, allowing the ear to disperse its seeds. In short, a simple change in position determined by a single gene change can provide a mechanism for dispersal of the seeds borne on the ear as well as those borne on the fragile branches of the tassel.

These facts seem to answer several of the most puzzling questions involved in previous attempts to explain corn's evolution: How could wild corn have survived the handicap of an ear incapable of dispersing its seeds? And if wild corn had no ears, how could the ear of modern corn, its most important organ, have come into existence?

The position of the ear has an effect on still another characteristic illustrated in figure 3, the length of the streamers or leaf blades which in many varieties terminate the outer husks. The higher the ear, the more likely are the leaf blades to be short or absent. This may explain the absence of leaf blades in prehistoric husks found both in Bat Cave [5] and in La Perra Cave [8].

MODERN AND PRIMITIVE CORN COMPARED

The most primitive ear we have so far obtained by combining popcorn and pod corn is shown in plate 3, figure 3, in comparison with an ear of modern dent corn and with the most primitive cob, dated at $4,445 \pm 180$ years, from La Perra Cave, which was excavated by Richard MacNeish of the National Museum of Canada.

In weight and number of kernels our reconstruction is much closer to the prehistoric La Perra specimen than to the ear of modern dent corn. The modern ear weighs 317 grams. The ear of pod-popcorn weighs 1.99 grams. However, only 24 of its 38 female flowers developed kernels. Had all done so, it would weigh 2.47 grams, assuming the additional kernels to have the same average weight, 0.034 gram, as those which are present. The La Perra specimen weighs only 0.52 gram, but it lacks both the 48 kernels, which it once bore, and a male spike. Without its kernels and its male spike, the reconstructed ancestral form weighs 0.87 gram, only slightly more than the prehistoric specimen.

Although we have not yet completely reconstructed wild corn, or duplicated exactly the most primitive specimens from either Bat Cave or La Perra Cave—the glumes of the pod-popcorns are still too

prominent to match those of the prehistoric specimens—we have succeeded in developing what is probably the world's most unproductive corn. This is useful in suggesting that we are on the right track in attempting to retrace corn's evolutionary paths.

The reconstructed ear illustrated in plate 3, figure 3, has female flowers on its lower half and male flowers on the remainder. This, as figure 3 shows, is a characteristic of ears borne in a high position on the stalk. If our reconstruction is valid, should not prehistoric ears also bear male flowers? A reexamination under the microscope shows that at least some of them once did and that these have since been lost in handling. Some of the ancient cobs, including the one illustrated in plate 3, figure 3, have stumps, previously unnoticed, of a slender stem on which male flowers were undoubtedly borne. Thus our genetically reconstructed ancestral form has taught us to look for a characteristic in prehistoric ears which we had previously overlooked. It has also shown us the significance of ears bearing terminal male spikes which are still found in certain races of corn in the countries of Latin America: the races Nal-Tel and Chapalote of Mexico (9), Pollo of Colombia (10), and Confite of Peru. Finally it may explain some curious ears, which had previously puzzled us, molded in bas relief on a prehistoric Zapotec funerary urn from Mexico. The urn is shown in plate 4, figure 1, and the details of one of the ears in plate 4, figure 2.

In bearing both male and female flowers these ears of pod-popcorn also resemble the lateral inflorescences of *Tripsacum*, a perennial grass and a wild relative of corn (pl. 3, fig. 3). This resemblance has in turn called attention to additional characteristics in which the reconstructed corn resembles *Tripsacum*: (1) the flowering of the female spikelets before the male in both lateral and terminal inflorescences; (2) the many-stalked condition; (3) the small, hard, pointed seeds.

Actually this reconstructed corn might easily be classified as an annual form of *Tripsacum*, or conversely, since corn was the first of the two to be given a Latin name, *Tripsacum* could be classified as a perennial form of the genus *Zea*, to which corn belongs and which, until recently, has been represented by the single species *Zea mays*.

These unexpected results of combining popcorn and pod corn—the production of a counterpart of corn's wild relative, *Tripsacum*—we regard as additional evidence that our reconstruction has validity.

EVOLUTION UNDER DOMESTICATION

Figure 4 illustrates some of the principal environmentally induced and genetically controlled changes which are believed to have occurred during domestication. The first three plants illustrate the genetically reconstructed ancestral form as it would be expected to

develop in three different environments. The first plant, a short, single-stalked plant with a slender, unbranched tassel bearing both male and female flowers and no ears, is intended to represent the wild corn plant growing in nature in a site of low fertility and in severe competition with other natural vegetation. Such a plant would barely reproduce itself.

The second plant represents this same genotype grown under primitive agricultural conditions. Here it is still single-stalked but under these somewhat better conditions is capable of producing a branched tassel and a single small ear borne high upon the stalk. The third plant (a counterpart of the third plant in pl. 3, fig. 1) represents the genetically reconstructed ancestral form grown under modern agricultural conditions with an abundance of fertilizer and in freedom from competition with weeds. Under these conditions it has several stalks as well as several small ears on each stalk. Plants like these might also have occurred sporadically in the wild under unusually favorable natural conditions.

The ability of the wild corn plant to respond in a spectacular fashion to freedom from competition with weeds and to high levels of fertility is undoubtedly one factor which led to its domestication. This ability to take full advantage of the improved environment usually afforded by an agricultural system is one of the characteristics found in almost all highly successful domesticated species. There are many wild species which do not have this trait; they cannot stand prosperity.

Since the corn plant is genetically plastic as well as responsive to an improved environment, domestication may soon have brought other changes, which are illustrated in the last four plants in figure 4. One of the most important of these was a mutation at the pod-corn locus on the fourth chromosome. This single genetic change had numerous effects. It reduced the glumes which in wild corn completely surrounded the kernels, and the energy released from chaff production now went into the development of a larger cob, which in turn bore more and larger kernels. The mutation also lowered the position of the lateral inflorescences, and this had profound effects of several kinds which can be understood by referring again to figure 3. This shows that: (1) The lower the ear, the stronger the stalk at the position at which the ear is borne and the greater its capacity for supporting large ears. (2) The lower the ear, the more likely it is to bear only female flowers which develop kernels when pollinated. (3) The lower the ear, the longer the shank, the branch on which it is borne, and this in turn has a number of important secondary effects: the longer the shank, the more numerous its nodes or joints and the husks which arise from them; the greater the number of

husks, the more completely the ear is enclosed and the less capable it is of dispersing its seeds.

In short, a rather simple change but a very important one, the lowering of the position of the ear (comparable, perhaps, to moving the engine of a primitive airplane from a position behind the wings to one in front of them), has separated the sexes, and made for a larger strictly grain-bearing ear which is completely protected by the husks and is no longer capable of dispersing its seeds. In short, a mutation at a single locus on chromosome 4 has made the corn plant less able to survive in nature but much more useful to man.

The last two plants in figure 4 show some of the changes which human selection has subsequently effected. Selection for large ears has tended to eliminate the secondary stalks and to reduce the number of ears per stalk. The fifth plant in figure 4 represents a typical New England flint corn in which the secondary stalks have been reduced to low tillers, known to the farmer as "suckers," which in days of cheaper labor were often removed under the erroneous impression that their removal was a kind of beneficial pruning operation. The last plant represents a typical Cornbelt dent corn which is predominantly single-stalked and often bears only one ear, in approximately the middle region of the stalk.

The corn plant has a distinct advantage over other cereals in bearing its ears in the middle region of the stalk, which, being thicker and stronger than the tip, is capable of supporting a larger ear. This is a simple and obvious mechanical advantage. There may also be a less obvious but even more important physiological advantage. We have evidence⁴ that, under otherwise constant conditions with respect to the genotype and the environment, a decrease in the weight of the tassels may be accompanied by an increase five times as great in the weight of the ears. There is at least little doubt that corn, by virtue of its botanical characteristics, is potentially more productive than the other cereals. For example, record yields of wheat seldom exceed 100 bushels per acre; the maximum yields of corn recently reported are more than 300 bushels per acre.

There have, of course, been other factors, not discussed here, in corn's evolution under domestication: mutations at many loci in addition to that governing the characteristics of pod corn; extensive hybridization among distinct races [9, 10]; repeated hybridization with teosinte [8, 11] and perhaps also with *Tripsacum* [6]; and human selection for many different characteristics. But it was this one mutation at the pod-corn locus—this single change in a molecule of the hereditary material—which more than any other factor has determined the botanical characteristics of modern corn and which

⁴ A report on this evidence is in preparation.

set the plant upon new evolutionary paths that have made it more useful to man and more dependent upon him for survival.

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The Need To Classify¹

By ROGER L. BATTEN

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[With 1 plate]

ONE of mankind's earliest intellectual endeavors was the attempt to gather together the seemingly overwhelming variety presented by nature into an orderly pattern. The desire to classify—to impose order on chaos and then to form patterns out of this order on which to base ideas and conclusions—remains one of our strongest urges. This same desire is the basic stuff of science.

The classification of living forms is a complex endeavor. It is also a constantly changing one. Even to this day, as new organisms are discovered, we are often faced with the need to revise past systems of classification—and we are never quite satisfied with the latest system.

How do these classifications of life serve us? One of their most exciting uses is in unraveling the extremely tangled record of life's evolution during the 500 million years for which we have records of organisms.

In biology, the description of newly discovered organisms is not so common today as it was 50 years ago. In paleontology—the study of the remains of formerly living organisms—however, the job is far from complete. This is because it is not nearly so easy to obtain fossils as it is to collect living specimens: even after fossils are found in rock, it requires much painstaking preparation just to see the characters by which they can be classified. Almost daily in the field of paleontology, newly discovered fossil forms are being analyzed and described.

It is easy to see that such discoveries require almost continuous change in our systems of classification. For it follows that, as more information accumulates, the “new” forms must be incorporated in the classification and our concepts of the relative positions and interrelations between various groups of organisms must also change. For formal classification is, in essence, a rather artificial structure—a tool

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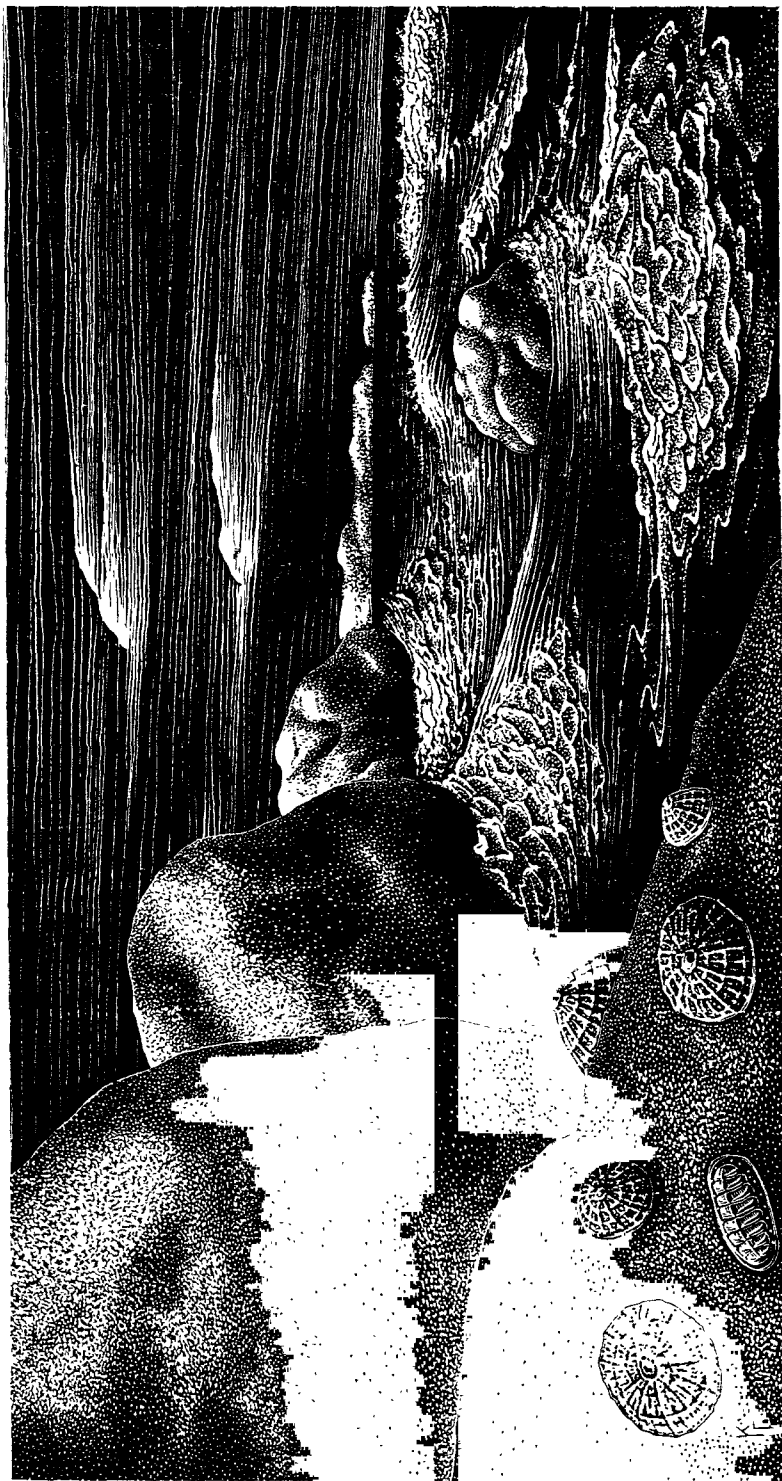


FIGURE 1.—Rocky seashore provides a natural setting for this group of marine mollusks (foreground). The five cap-shaped mollusks are patellids, rock-clinging "true" limpets, members of the class Gastropoda. The long, narrow chiton (lower left foreground) is of the class Polyplacophora. Early classifiers believed that all cap-shaped gastropods belonged in one group.

used to express current ideas regarding the relationship of organisms one with another.

From the first, mankind classified the things he observed by a method which declared that "like things belong together." This method was implicit in the first classification of living things and remains the chief method of classifying today. But it is a method that must be used with discretion for—as we shall see—one can very easily classify objects on the basis of their superficial resemblances, while overlooking important basic characteristics which may be somewhat less obvious.

As an example, we might say, "I will construct a category for animals that fly." Such a single category would include many flying animals that were more or less related. But birds and bats would occupy the same category, because both possess flying appendages. Upon closer examination, however, we would note that the wings of a bird and a bat are actually quite different. Further examination of the other organs of birds and bats would show that, while these two animals are superficially alike, in detail they are not at all closely related. If we were sensible, we would change our classification to recognize these differences.

Refinements of a classification—although considerably more subtle than in this example—are a daily and important part of work today that aims at achieving a framework which reflects the relative degree of relationship both between contemporary organisms and between the animal forms of the evolutionary past.

Let me now relate a case that demonstrates how our knowledge has increased over the years and show some of the effects that this increased knowledge has had on classification. We will take the phylum Mollusca, and, within this phylum, chiefly the snails (which in classification are called the class Gastropoda). In addition to the snails, other classes belonging to this same phylum include:

Phylum MOLLUSCA:

Class POLYPLACOPHORA (chitons)

Class PELECYPODA (clams)

Class CEPHALOPODA (octopus—chambered nautilus)

Class SCAPHOPODA (tusk shells)

We know that among the myriad of snails that make up the class Gastropoda (some 50,000 species are known to exist) there are several groups, collectively known as the "limpets," which are peculiarly adapted to a rocky environment where surf or swift currents present rather rigorous conditions for life. These limpets have cap-shaped shells, and possess powerful muscles that enable them to adhere to rocks, even under the stress of pounding surf (figs. 2 and 3).

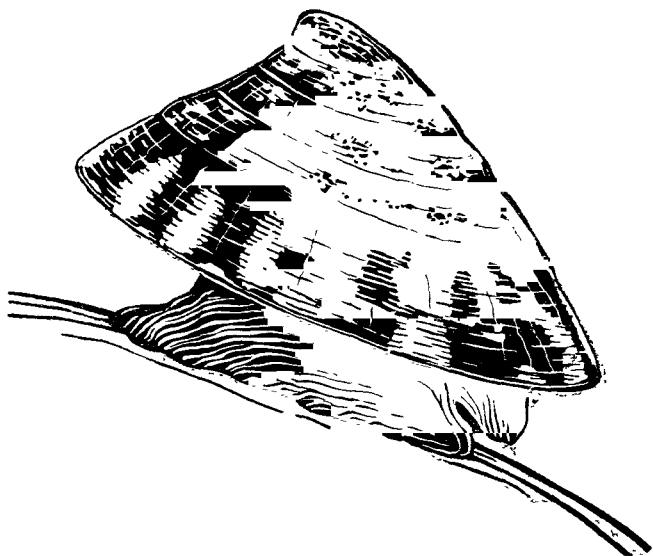


FIGURE 2.—Living limpet, *Acmaea*, is shown attached to a rock, its shell raised somewhat higher above the fleshy foot than normal. Limpet's front faces to the left.

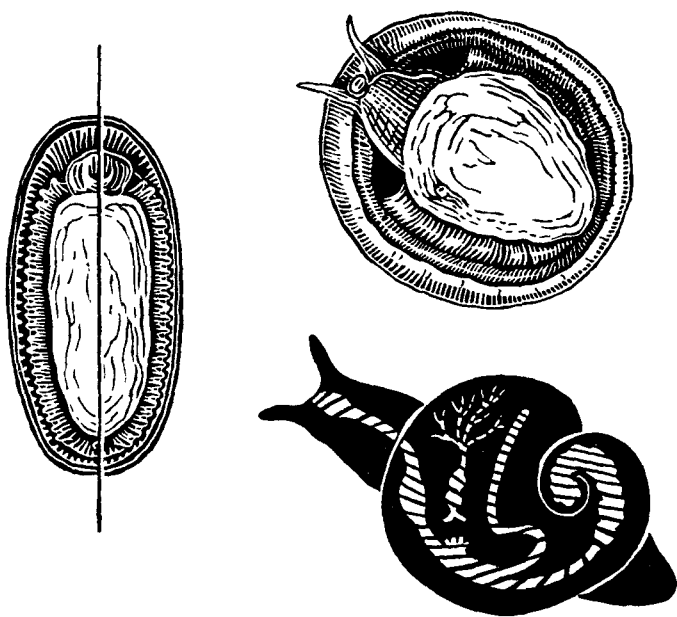


FIGURE 3.—Bilateral symmetry of chiton (left) with mouth and anus at opposite ends, contrasts with curled, one-sided patellid and snail (right) where same organs lie in close proximity.

As we know today, there are several families of gastropods having representatives adapted to life in such rough and rocky environments (fig. 6). All of them possess shells that are superficially quite similar, since they share a common habitat. Early zoological classifiers, looking at these cap-shaped shells, assumed that these different gastropods were members of the same group. The paleontologists, too, when they began to turn up such shells in the fossil record, classified all the cap-shaped shells as members of the limpet group. The classification, as formed by them, showed one group of "limpets" from very early geologic time to recent times. Such a classification would look like the illustration shown in figure 4.

Meanwhile, the biologists—who were studying living limpets—soon recognized that, in addition to the "true" ones (which they called patellids), there actually were several other more or less distantly related families of gastropods, members of which resembled true limpets.

This discovery was possible because the biologists studied the living tissue and organs. Unfortunately, the paleontologists had only the shells available, and were unable to study the differences in the organs between the various cap-shaped forms. For many years, in consequence, little change occurred in classification of the extinct forms.

Before we go further, we must learn something more about the gastropods. Most organisms, we know, possess some sort of symmetry in their bodily arrangement. The commonest type of symmetry is a bilateral arrangement, in which one side of the organism is a mirror image of the other, and the organism's head and tail lie at opposite ends of the body. Most gastropods are asymmetrical, having lost one "side" sometime in the course of their evolution. When we look at a snail, we see that the soft parts of its body are contained in a shell which, although often coiled, is usually a long, narrow cone, open at one end (see fig. 3).

An examination of rock-clinging patellids—the true limpets—shows that, while they have cap-shaped rather than long, narrow shells, here, too, only one "side" of the organism is present and anus and mouth are in close proximity. In other words, all the limpets are typical, coiled asymmetrical gastropods (see fig. 5).

We have already been introduced to another class in the order of mollusks—the polyplacophorans, or chitons. These chitons share a rock-clinging environment with the limpets, but they are a much more primitive form of mollusk. Anus and mouth are at opposite ends of the chiton's body and the body itself is bilaterally symmetrical. The chitons' shells are different from those of the patellids, having eight separate plates instead of a single shell (see fig. 9). It was thus obvious—even to the early classifiers—that, while these two

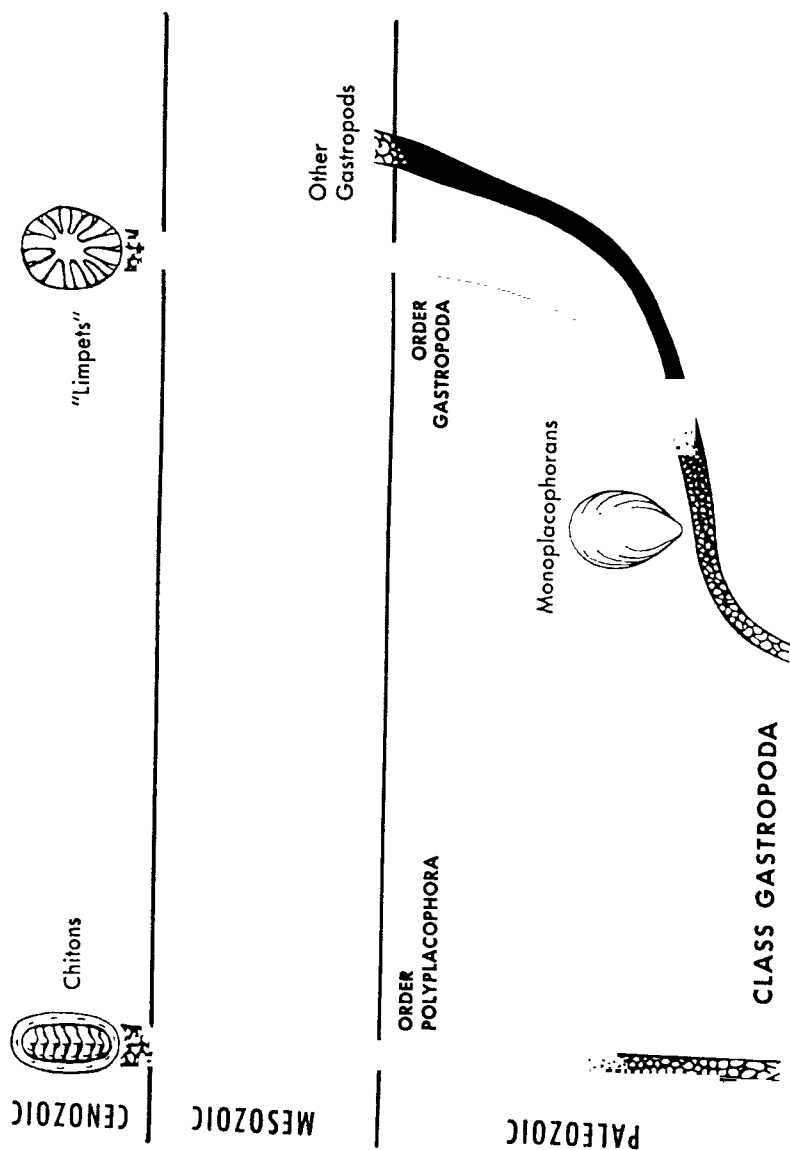


FIGURE 4.—Early classifiers put all cap-shaped mollusks, including the fossil monoplacophorans, in a single line of limpets extending to early geologic times. Chitons were separate.

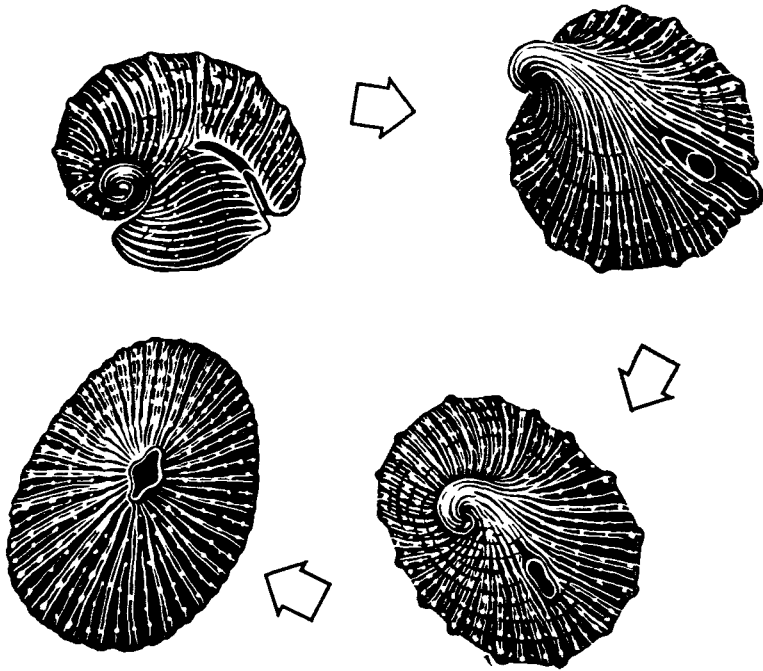


FIGURE 5.—Growth of rock-clinger, from early whorl to final cap-shaped form, is seen here with *Fissurella*, the keyhole limpet, another large limpet group belonging to the superfamily Fissurellacea of the Archeogastropoda. First three growth stages are shown greatly magnified.

organisms shared a similar environment, they were vastly different from each other. What was not so apparent, however, was that some of the gastropod groups that possessed cap-shaped shells were very different from other gastropod groups that also possessed such shells.

A few years ago, paleontologists attempted to reclassify some cap-shaped fossil shells that dated back to the early Paleozoic. With no soft parts to examine directly, they critically studied these shells for characteristics that could be related to the absent tissue. In the study of living patellids, it had been noted that a continuous “muscle scar” ran around the inside of their shells, marking the attachment area for the limpets’ powerful muscles. The paleontologists found that many of the fossil shells exhibited such a continuous “muscle scar.” Therefore, they felt safe in assuming that the missing soft parts had been similar to those found in living patellids.

However, the paleontologists also discovered that other cap-shaped shells possessed, instead, two to eight pairs of distinct “muscle scars.” Two things were curious about these ancient muscle scars: first, some were eight in number and, second, they were arranged around the shell in bilaterally symmetrical pairs. The paleontologists could only speculate that these shells were, in fact, so primitive that the

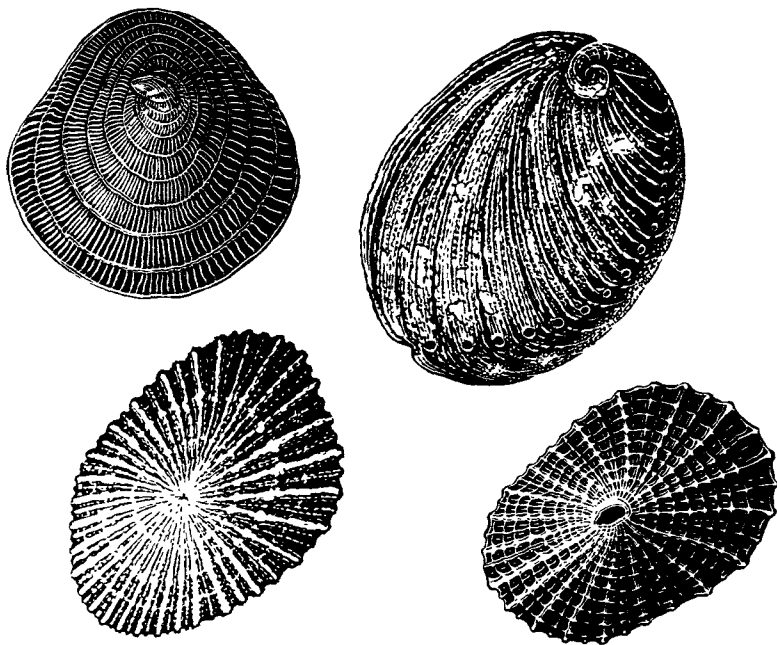


FIGURE 6.—Only “true” limpet among these rock-clinging gastropods is the patellid at bottom, left. The others, quite similar in form, are, clockwise, *Crucibulum*, belonging to another order (Caenogastropoda), *Haliotis*, belonging to the superfamily Pleurotomariacea of the Archeogastropoda, and *Diodora*, another fissurellid.

organisms had not yet lost one of their “sides.” They concluded that these primitive forms, unlike most gastropods, had possessed bilaterally symmetrical soft parts (fig. 10).

If this conclusion was true, then the paleontologists had discovered the probable ancestral group from which later gastropods were derived. Indeed, it seemed possible that not only were these forms (which are called monoplacophorans) the basal stock for the gastropods, but for the eight-plated chitons as well. Here, then, was some evidence with which to construct a new classification—one that had brought together two groups previously widely separated: the class Polyplacophora and the class Gastropoda. Such a classification is illustrated in figure 7. This new interpretation made it possible, for the first time, to relate two diverse groups as well as to understand something of the evolution of these groups.

The never-ending labor of classification, whether it is the work of biologists or paleontologists or others, receives contributions from all. Shortly after the Smithsonian paleontologists’ announcement² of this particular revised classification, a serologist—studying blood types in the mollusks—proved that the gastropods and chitons could *not*

² Knight, J. Brookes, Primitive fossil gastropods and their bearing on gastropod classification. Smithsonian Misc. Coll., vol. 117, No. 13, October 29, 1952.

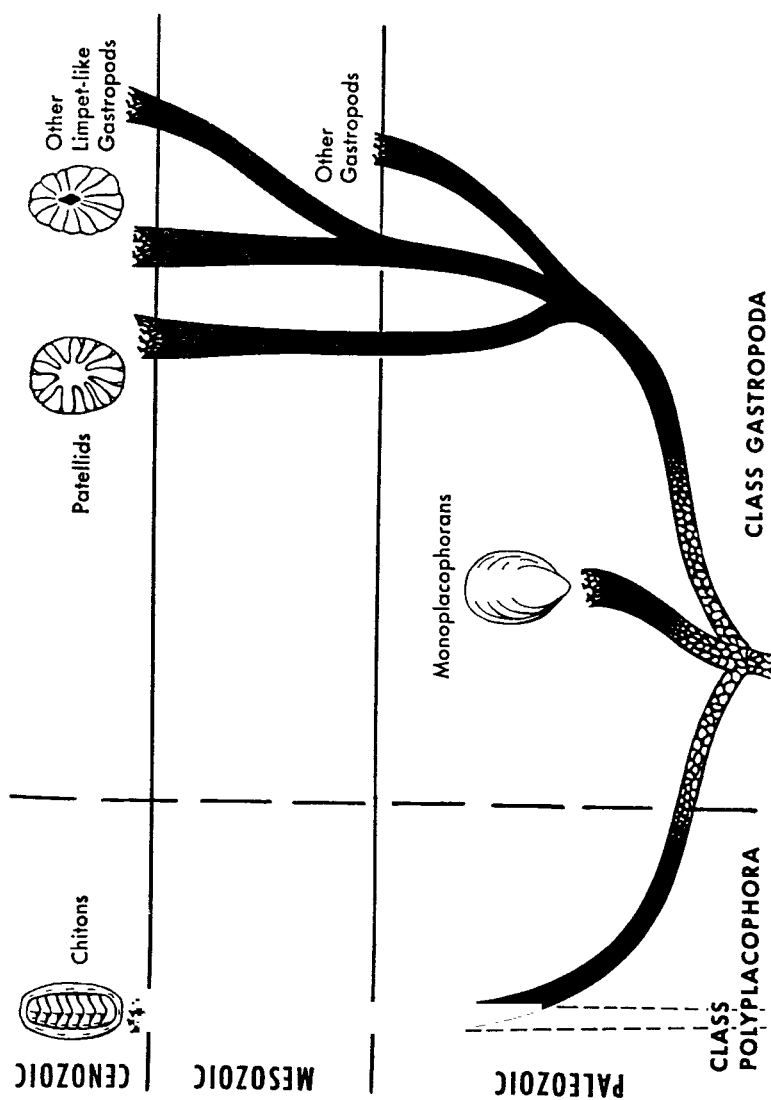


FIGURE 7.—Revised classification incorporates both the biologists' analysis of differences between "true" limpets and the rest of the rock-clingers and the paleontologists' discovery of bilateral symmetry in arrangement of fossil monoplacophoran muscle scars. New arrangement envisions latter as ancestral stock not only for all gastropods but also for the chitons.

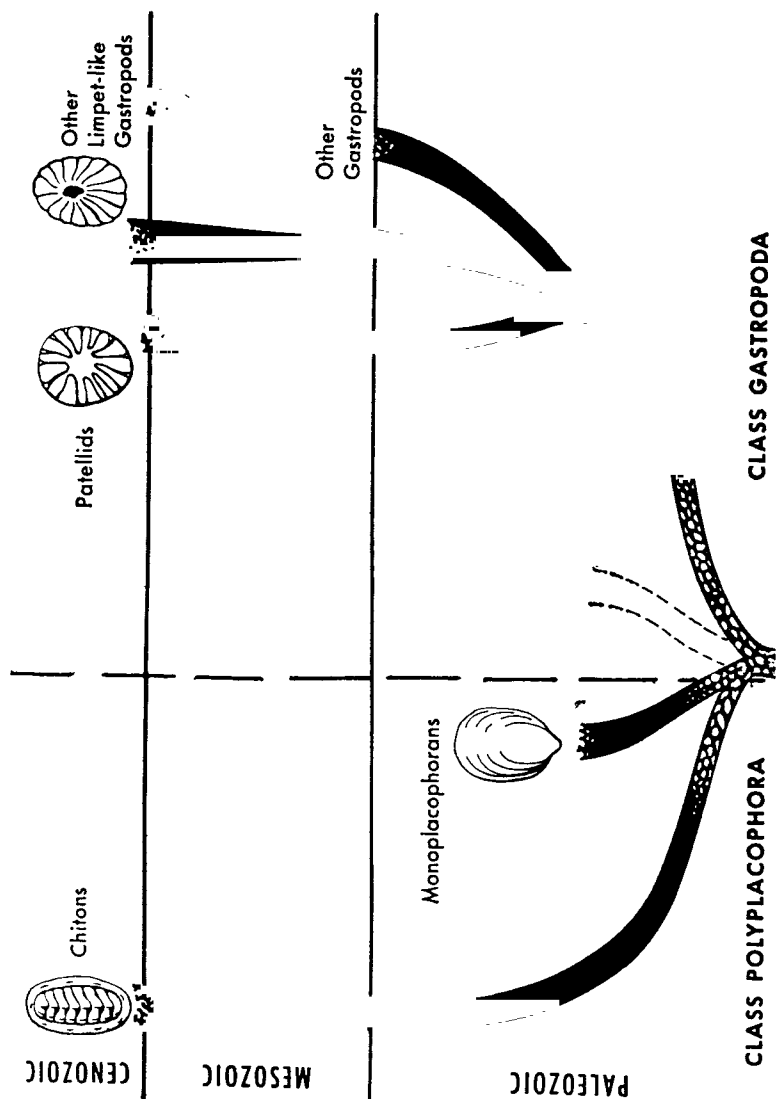


FIGURE 8.—Mollusk blood-type study proved that chitons and gastropods could not be so closely related as the classification (fig. 7) had proposed. Thus, a further revision of the classification was made (above). This put the fossil monoplacophorans in with the chitons, and the gastropods off as a branch of the chiton stock. This hypothesis stood until 1957.

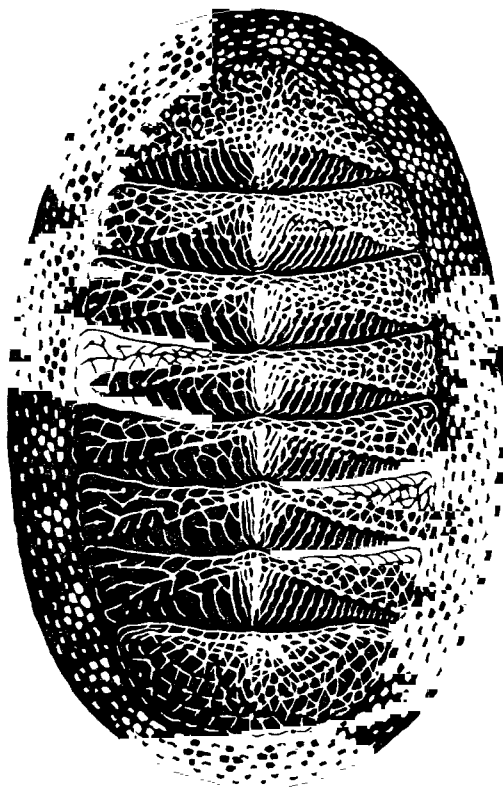


FIGURE 9.—Top view of chiton shows eight separate plates of its shell.

be so closely related as the revised classification proposed. It was necessary, therefore, to revise the classification further, so that the monoplacophorans were placed in with the chitons, while the gastropods were viewed as a branching-off from the chiton stock.

Again, a major change in classification had been made, in order to fit newly discovered facts (fig. 8).

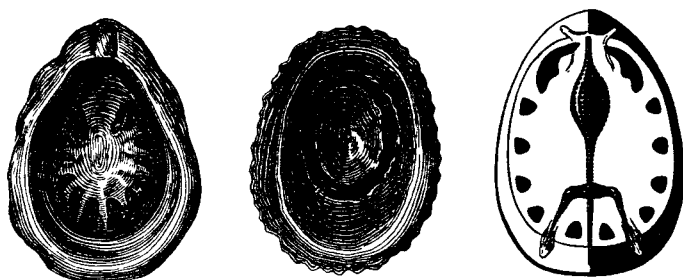


FIGURE 10.—Multiple muscle scars of fossil monoplacophorans (left) are contrasted here with the continuous, ringlike muscle scar of a fossil patellid. With this clue to bilateral symmetry, the paleontologists reconstructed a hypothetical set of symmetrical body organs for the monoplacophorans (right) in which anus and mouth lie at opposite ends of the animal.

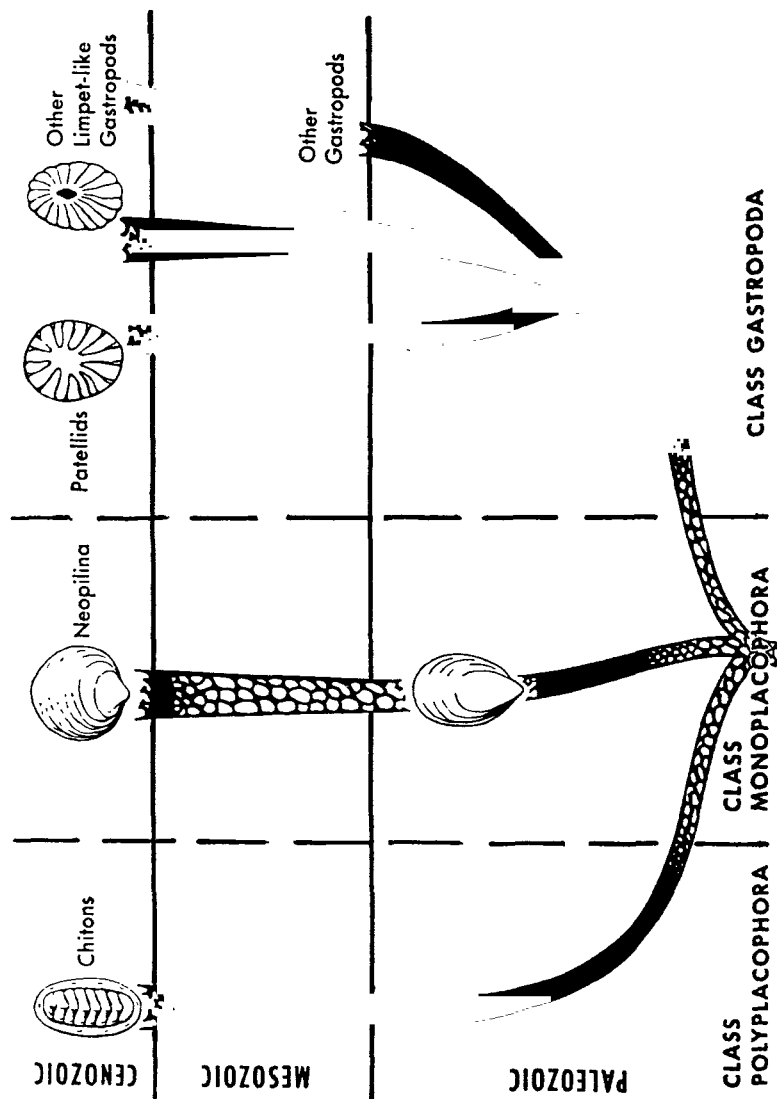


FIGURE 11.—Latest classification, which incorporates the first major revision of the mollusks since 1876, establishes a new category, the Class Monoplacophora. This revision stems primarily from *Neopilina* discovery but the author points out that the new version, like the earlier ones, subject to change in the light of new facts, combines the findings of many disciplines.

Thus, up to 1956, stood the classification of the primitive forms of gastropods—a far cry from the first classification that had viewed all the limpets as members of one family.

Now, looking at the fossil record, we can make another observation. The primitive monoplacophorans were not a successful group of animals: they apparently became extinct about 280 million years ago—probably giving way to the more advanced limpets, which could more successfully adapt to the environment of that time. But about 8 years ago, during the expedition of the Danish vessel *Galathea*, several tiny cap-shaped shells were brought to the surface by the deep-sea dredging operations. The natural first impression was that they were limpets, because no other group of cap-shaped shells were known to be extant. Upon careful examination in the laboratory, however, some sharp differences were noted between these forms and the usual gastropods adapted for rock-clinging environment. This new form, duly described and named *Neopilina galathaea*, was presented to the astounded scientific world early in 1957. Others have been found since then. For here was a living monoplacophoran, previously thought to be extinct for 280 million years! (See fig. 12 and pl. 1.) *Neopilina*, with its eight distinct muscles and bilateral symmetry—mouth and anus at opposite ends of its body—is the very organism hypothetically constructed by the paleontologists 5 years before.

Many of the characters of *Neopilina* predicted by the paleontologists were found: several other characters that could not have been predicted were also present. These additional characteristics are bringing even further changes in classification. One major discovery is the presence in *Neopilina* of what appears to be body-cavity segmentation, and a separate gill for each of the paired muscles. Segmentation of the body cavity is considered by zoologists to be a primitive characteristic. Such segmentation is shared by several very different phyla, including the worms and the arthropods (that great group which includes such diverse forms as lobsters, spiders, and insects).

One suspects that there will be a strong temptation to revise classification in a manner which will relate some of these diverse forms more closely than is the case at present.

In our own task of unraveling the complex relationships between various primitive mollusks, the discovery of *Neopilina* has sent the paleontologists back to further study of their collections. Perhaps some minor feature, overlooked before, will now have great significance. Already some of the rather vague muscle scars of fossils that had been placed in other gastropod families indicate that these belong, instead, among the monoplacophorans.

The search is far from completed; it will take several years for all of us to understand and reevaluate our data. So far, we know much more about how the gastropods and other mollusks came to be and,

yes, we have made still another change in the classification! We know now that the monoplacophorans are *not* gastropods and—even more important—are *not* chitons, either. How are we to represent this in our classification? We will erect a brand new class, the class Monoplacophora, the first new class to be erected since 1876, when the chitons were separated from the gastropods. The new classification will then look like the illustration shown on figure 11.

Thus, the work of a variety of scientists—a discovery off the coast of Costa Rica, the study of blood types, and the examination of obscure fossils—have wrought major changes in the classification, and by so doing have moved man toward a better understanding of the great stream of life.

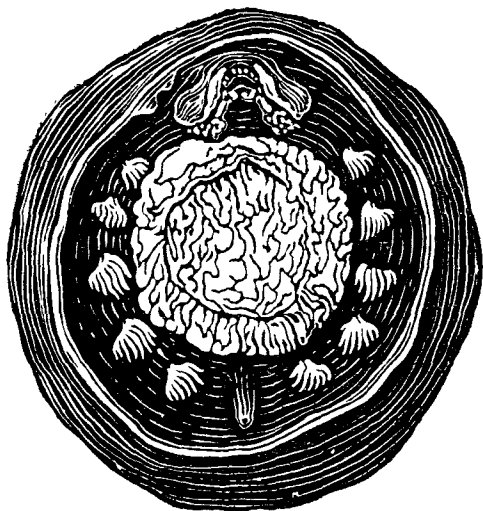
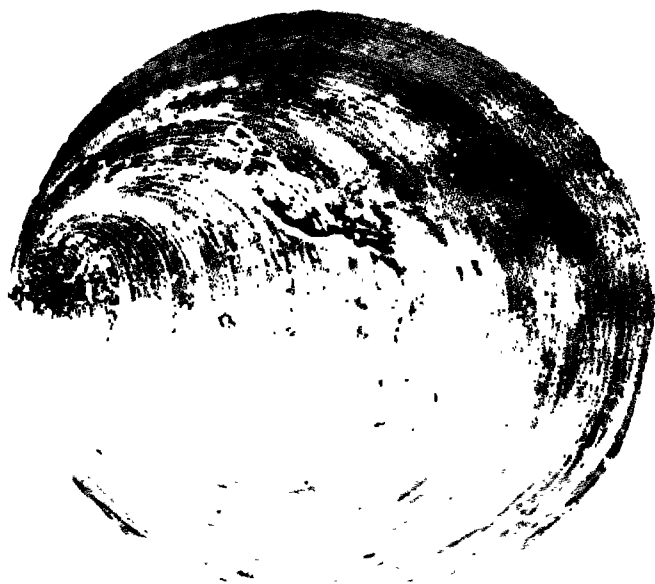
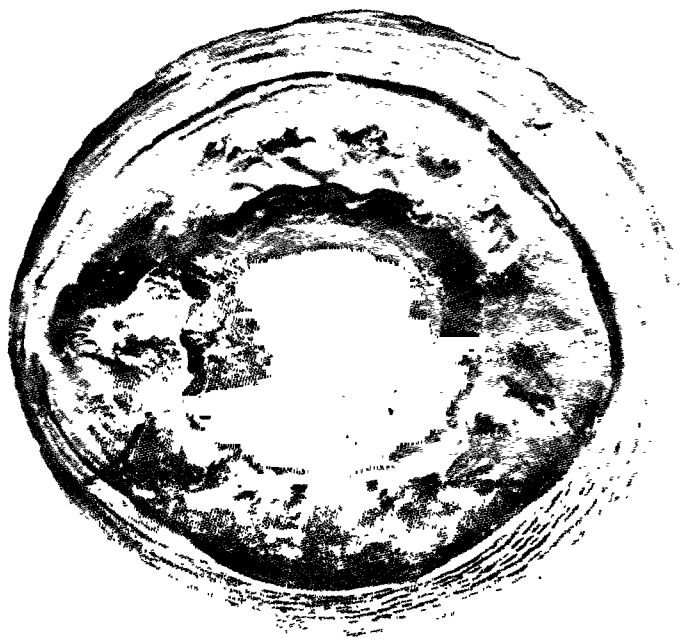


FIGURE 12.—The astonishing recovery of a living monoplacophoran by the *Galathea* Expedition in 1951 (bottom view above) gave confirmation to the paleontologists' hypothetical reconstruction.



Living monoplacophoran, found by Danes off Costa Rica in 1951, was christened *Xopilina galathica*, during the Galathica Expedition. Top (left) and bottom views here come from the expedition's leader, Anton Bruun. Detailed study of the new mollusk, whose fossil cousins have been extinct for 280 million years, appeared in 1957 and 1960.

Current Advances and Concepts in Virology¹

[With 4 plates]

THESE VERY WEE ANIMALS

"THE FOURTH SORT of little animals, which drifted among the three sorts aforesaid, were incredibly small; nay, so small, in my sight, that I judged that even if 100 of these very wee animals lay stretched out one against another, they could not reach to the length of a grain of coarse sand. . . ." This quotation is attributed to Anton van Leeuwenhoek, a Dutch linen draper, who was the father of microscopy and probably the first to see bacteria (1).²

Many years later, attempts were made to remove these very wee animals. Cotton plugs and porous unburnt clay were used, and, in 1877, Pasteur employed plaster of paris to separate anthrax bacilli from their containing fluids.

In 1891, Nordtmeyer introduced a new filter medium made of compressed infusorial earth known as Kieselguhr. The filtering capabilities of this substance were noticed because the ground water in the Kieselguhr mine in Unterluss (Hannover) was of a clear blue color. The filter of Kieselguhr, which is still used today, was called "Berkefeld," after the owner of the mine. These filters are capable of holding back the smallest bacteria, and fluids which have passed through them are bacteriologically sterile. Yet, infections may be produced by such sterile fluids because the causative agents—viruses—have filter-passing ability as a typical characteristic.

Actually, the first scientific demonstration of the existence of a virus disease must be accredited to Ivanovski, a Russian botanist, who, in 1892, was investigating a disease of the tobacco plant known as tobacco mosaic. This worker extracted some of the sap from a diseased plant and passed it through a fine filter made of unglazed porcelain. He then discovered that the filtrate, although sparkling clear

¹ Prepared by members of the medical staff, Lilly Research Laboratories. Reprinted by permission from *Physician's Bulletin*, vol. 24, No. 3, Apr. 1, 1959, published by Eli Lilly & Co., S. O. Waife, M.D., editor.

² Numbers in parentheses indicate references at end of text.

and free of all bacteria, had the power of producing the disease when rubbed on the leaves of healthy tobacco plants. Despite the evidence of this experiment, Ivanovski himself, as well as the scientists of his day, believed that the disease was caused by bacteria.

Seven years later, this phenomenon was rediscovered by Beijerinck, who extended these observations and recognized that a new type of agent had been discovered. He gave it the appropriate name *contagium vivum fluidum*—a living contagious fluid.

Although the discovery of the existence of viruses is of recent date, virus diseases have played a long historic role in the life of man. Smallpox existed in China as early as 1700 B.C., and yellow fever was recognized as early as the 17th century. In fact, the establishment of the Haitian Republic was largely due to yellow fever, since most of the French troops sent to invade the island died of the disease there.

Of course, long before the microbiologic era in medicine, a method of preventing one infectious (virus) disease had been devised and its use thoroughly established; namely, vaccination against smallpox (Jenner). Yet it is curious that, in spite of its ancient lineage, virology has only recently burst forth into full bloom as a vigorous, if not explosive, branch of medical science.

The following pages present a few of the highlights of current advances and concepts in virology.

WHAT IS A VIRUS?

The submicroscopic particle known as a virus stands in the limbo between "living things" and chemical compounds. No longer does one ask, "Is a virus a plant or an animal?" Rather, one asks, "Isn't it a complex chemical (a nucleoprotein) with both the actual and potential properties of life itself?"

We now know that a virus consists grossly of a protein shell around nucleic acid material. It may be, however, that this description is too simplified. At any rate, the shell is made up of many small, symmetrically arranged protein molecules. The protein coat may be, like most proteins, antigenic. Antibodies produced against this antigen can "neutralize" the virus. Thus, antiserum would seem to be useful. However, it can act only on virus in serum before it enters a cell; and, since this is a transient phase in the life cycle of these tiny particles, little clinical use can be made of antisera (2).

Inside the protein coat is nucleic acid material which in many viruses consists of ribonucleic acid (RNA). Other viruses, including those which attack bacteria (bacteriophage), contain deoxyribonucleic acid (DNA). In animal tissue, DNA is largely nuclear and RNA cytoplasmic in location.

Nucleic acids are complex chemical molecules. They consist of a double spiral of long chains of sugar-phosphate-purine (or pyrimi-

dine) groups; one such unit is called a nucleotide. RNA differs from DNA in the sugar moiety. The complexity of nucleic acids can be judged from the fact that thymus DNA has a molecular weight on the order of 4,000,000 and contains about 10,000 nucleotides.

Infectivity and the capacity to damage or destroy cells are said to be functions of the nucleic-acid content.

Viruses vary considerably in size and, to some extent, in shape. The largest measure about 300 millimicrons ($m\mu$) in diameter, the smaller about one-tenth of this or less. (In comparison, a staphylococcus has a diameter of about 1,000 $m\mu$.) Their configuration, as determined from advanced technics, may be classified roughly into spheres, rods, and ellipsoids (pl. 1).

CLASSIFICATION

No satisfactory classification comparable to bacterial groupings has been devised for viruses. These individualistic creatures do not seem to fall into a logical pattern. They may be grouped according to their primary site of action, antigenic relationship, mode of transmission, pathologic tissue reactions, immunologic properties, etc. Because we know a lot more about the diseases than about the organisms, the simple "clinical" classification provided in table 1 may be useful.

TABLE 1.—*Clinical grouping of selected virus diseases*

Dermatotropic:	Arthropod-borne:
Smallpox	Yellow fever
Chickenpox	Dengue
Herpes zoster	Encephalitides
Measles	
Herpes simplex	Psittacosis—Lymphogranuloma Group:
Exanthem subitum	Psittacosis
Respiratory—Parotid:	Lymphogranuloma venereum
Influenza	Trachoma
Mumps	Inclusion conjunctivitis
Adenovirus infection	
"Common cold"	Miscellaneous:
Neurotropic:	Coxsackie virus infection
Poliomyelitis	ECHO virus infection
Rabies	Verrucae
Lymphocytic choriomeningitis	Epidemic keratoconjunctivitis
Hepatic:	Foot-and-mouth disease
Infectious hepatitis	Salivary gland virus infection
Serum hepatitis	

MULTIPLICATION OF VIRUSES

It may come as a surprise to know that invasion by and multiplication of viruses are known in considerable detail. Some description of these processes is essential for a fundamental appreciation of the problems at the bedside.

Bacterial viruses.—Bacteriophage (phage, for short) has a specialized head and tail structure. Phage attaches itself to the surface

of the bacterium (pl. 2, fig. 1) by means of its "tail." The exterior coat may be likened to a disposable microsyringe, the function of which is to inject phage DNA into the bacterial cell (3). There follows a short period during which the virus cannot be detected by means currently at our disposal. Inside the cell, the virus DNA begins to make replicas of itself, using as raw materials the nucleic acids of the bacterial host and fresh substances absorbed by the bacteria from the surrounding media. The DNA also induces the synthesis of new protein in the cell, which in turn combines with the new DNA to form many new virus particles. Multiplication continues until the cell wall bursts and virus particles are released. (Notice a resemblance to invasion of red blood cells by malaria parasites.)

Animal-cell viruses.—The common viruses that infect man have no specialized tail-like mechanisms. However, they do attach to the surface of tissue cells, and there results a spreading disturbance along the surface which can be likened to a mucinolytic action (3). Some viruses, notably influenza, may be taken into the cell by an active process of ingestion by the cells themselves (pinocytosis). In contrast to phage, it is difficult to separate the phase of replication from that of maturation and release. This may be so because animal cells have much less rigid walls than do bacteria, and "new virus seems able to escape from the cells almost as soon as it is formed. In the case of influenza, Western equine encephalomyelitis, and poliomyelitis, there is a period after the infecting virus has penetrated the cells during which no infectivity is recoverable, followed by a period during which new virus is released from the cells in an exponential manner" (3).

Cellular infection by an animal virus may cause one or a number of centers to be set up for the manufacture of new virus particles, each of which can escape from the cell almost as soon as it is formed (pl. 2, fig. 2). Damage to the cell, however, is not correlated with the amount of new virus produced.

Lwoff et al. (4) studied the release of polio virus from single infected cells and found that once new virus was formed, it leaked rapidly from the infected cell. Cell death occurred when virus production ceased. Thus, escape of virus particles from infected cells causes only trivial damage to the cell surface.

GENES

According to the modern view of biology, almost all metabolic processes are catalyzed by enzymes, and all enzymes are protein molecules. The synthesis of enzymes is controlled by genes, and probably one gene controls the synthesis of one enzyme. A gene, therefore, must be able not only to duplicate itself as part of normal cell repro-

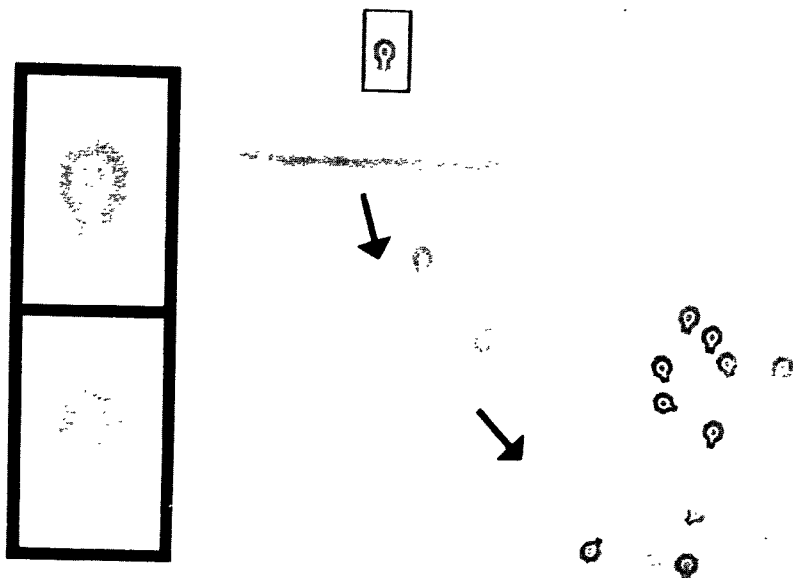


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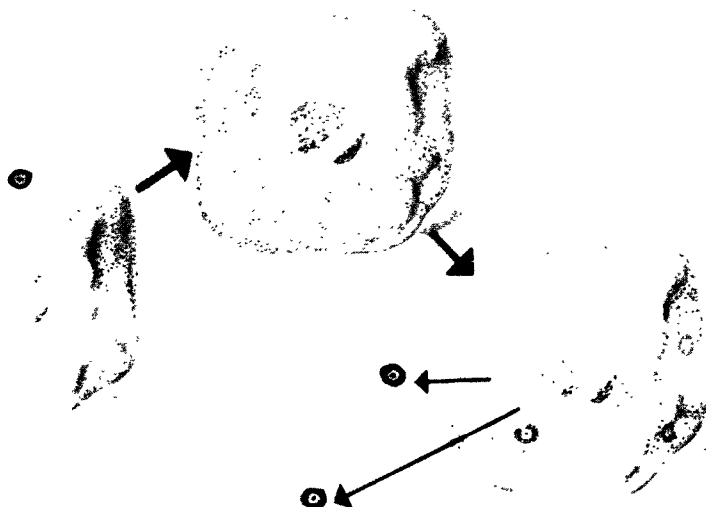
B

C

Various shapes of viruses ($\times 90,000$). A, Single particle of vaccinia virus. B, Influenza virus. C, Herpes simplex virus which has formed an intranuclear crystal.



1. Schematic representation of invasion by and multiplication of bacteriophage. In a short period of time bacterial lysis occurs. The figure represents T-coliphage attacking *Escherichia coli*.



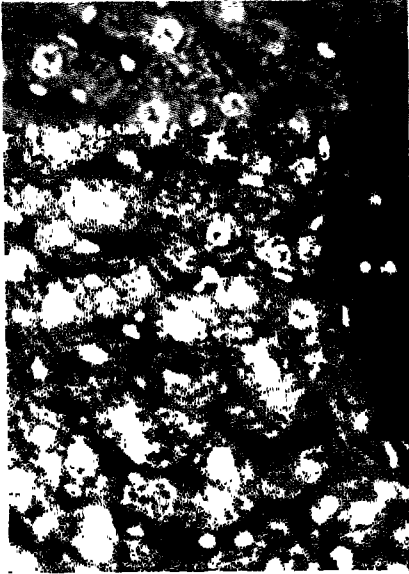
2. Schematic representation of virus invasion and multiplication in animal tissue cell. There is no "tail," and cell lysis does not characteristically occur.



1. Diagrammatic sketch of one segment of a DNA (deoxyribonucleic acid) molecule. The various squares represent the nitrogen-containing bases; the circles are the five-carbon sugar deoxyribose; the triangles are the connecting phosphate molecules.



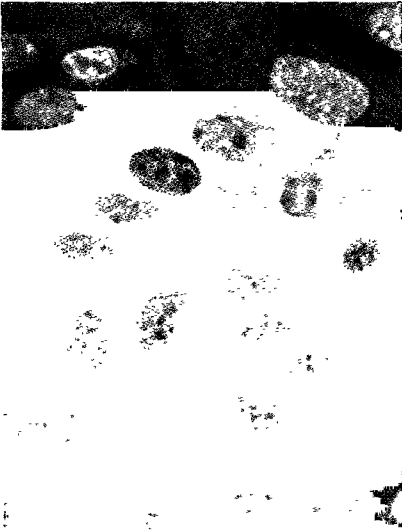
2. One concept of the self-replication of DNA. In this scheme the helical coils represent chains of nucleotides. Unwinding of the parent duplex (dark), replication, and rewinding of the duplicate (light) proceed simultaneously.



1. Normal liver. There is a flame-red fluorescence of cytoplasmic RNA. The nuclei, containing DNA, have a greenish-yellow color. ($\times 225$)



2. Normal salivary gland. Here the cytoplasmic RNA is situated at the base of the epithelial cells. Five tissue mast cells showing mahogany-red fluorescent granules are present. ($\times 225$)



3. Calf-kidney tissue culture infected 18 hours previously with influenza A (W.S. strain). Many of the nuclei show diffuse RNA fluorescence of varying intensity. The pattern of cytoplasmic RNA fluorescence is altered in many of the cells. ($\times 225$)



4. HeLa cells infected 2 days previously with adenovirus, type 5. This is a late stage of infection, and intensely fluorescing condensed masses of DNA-containing material occupy the center of some nuclei. An apparently normal nucleus is in the center of the field. ($\times 375$)

duction but also to determine the specificity of a protein molecule, i.e., the enzyme.

STRUCTURE OF GENETIC MATERIAL

What is transmitted in us from one generation to the next is not a characteristic eye pigment or blood type. Rather, it is a set of factors in chromosomes which are able to influence the activities of cells so that certain substances responsible for eye pigment or blood type are produced.

Current research indicates that chromosomes are largely composed of DNA,³ which suggests that this substance is a major constituent of genes. In fact, we can say that DNA, the basic stuff of all cell nuclei, is the sole carrier of genetic information in all organisms (except in small viruses, where RNA appears instead). The word "information" as used here means that genetic material tells the replicating cell what its characteristics are to be. This information is in a chemical "code" in the structural form of the molecule.

In spite of the complexity of its structure, the only variables in DNA are the purine, or pyrimidine, bases (adenine, guanine, thymine, cytosine), which are constant in any particular species. It appears that they are probably arranged in a definite sequence—which has been called the genetic code.

Each time a cell divides, an exact copy of genetic information must be made in order to insure continuity. Therefore, much interest is shown in structural features.

DNA would seem to be a double helix with the bases in each chain in a complementary sequence (pl. 3, fig.1). The two chains separate and make a duplicate of themselves, each offspring being an exact copy (pl. 3, fig. 2).⁴

RNA, not DNA, controls protein synthesis in the cell and may carry genetic information from nucleus to cytoplasm (5). Its structure is not completely understood.

Most protein is probably made in the *cytoplasm*, where the point of polymerization seems to have been traced to small spherical particles known as microsomes. These particles resemble spherical viruses in shape and composition. "This suggests that a virus infection may be equivalent to the injection of an apparatus for the manufacture of the wrong protein" (6).

The matter of genetic mutations, important in virology (such as the development of new virulent strains of influenza virus) as well as in clinical medicine, may also be explained in simple terms as the formation of an abnormal protein.

³ Sperm with half the chromosomes of a normal cell has about half the amount of DNA.

⁴ DNA can be extracted and transferred to another strain of bacteria and thus produces genetic transformation. When this transfer is made through infection by phage, it is known as transduction. The recent award of the Nobel Prize in Medicine went to Drs. Lederberg, Beadle, and Tatum for discoveries along these lines.

There is an important similarity between the structure of a protein and that of a nucleic acid. Both have a specific linear sequence of different units on a long chain,⁵ and both have a helical structure. Nucleic acids contain mainly 4 different kinds of bases; proteins contain mainly 20 different kinds of amino acids. The sequence of these units (adenine, guanine, thymine, and cytosine) determines the specificity of the nucleic acids, just as the particular sequence of letters specifies a word. In addition, it has been assumed by some that the sequence of the bases in the DNA-RNA chain determines the amino acids along the protein chain.

Thus far the reader may not see the tremendous significance of these "basic science" observations. However, consider sickle-cell anemia. This disease is due to an abnormal hemoglobin which harmfully affects the properties of the red cell. Very recently, Ingram (7) discovered that the abnormality consists only in the replacement of one glutamic acid residue by a valine—one of about 300 such amino-acid molecules in one of two identical halves of the hemoglobin molecule. This seemingly minor chemical change suggests a single mutation in the hemoglobin gene.

How much more lies just ahead in what is molecular biology today and medicine tomorrow?

VIRUSES AND CANCER

That viruses and cancer may be related is an old observation. Borrel suggested this in 1903 (8), and Rous (9) proved it a few years later. Viruses are now known to be found in such diverse neoplasia as human warts, fowl leukemia, rabbit papilloma, and milk-transmitted mammary cancer of mice (10).

Another interesting observation is the transformation of normal cells in tissue culture to tumor cells after introduction of sarcoma virus (11).

Many temporarily effective anticancer agents have been shown to affect nucleotide metabolism, and it appears that the rates of DNA synthesis and mitotic activity are parallel (12). Indeed, Cohen and Barner (13) have shown that cells (including bacteria) can be killed when DNA synthesis is blocked, even though RNA and protein metabolism may be unaltered.

Because relatively pure nucleic acid preparations which possess virus activity have been obtained, Stanley suggested (14) that "it would now appear wise to revise the generally accepted definition of a virus to include nucleic acids and perhaps also to include replicating structures which do not evidence infectivity in the usual sense,

⁵ The 1958 Nobel Prize for Chemistry was awarded to Frederick Sanger, of Cambridge, England, for working out the amino-acid sequence of insulin.

because normally they are duplicated only once or a minimal number of times during each cell division and may never leave the cell during many generations. Such a viral nucleic acid might temporarily appear to be a part of, or associated with, the genetic apparatus of the cell, but be subject to chemical or physical stimulation or shock which could cause it to mature, increase greatly its rate of replication, perhaps mutate, but in any case to separate and act as an independent functional unit."

DIAGNOSIS

At one time a diagnosis of virus disease was made by "exclusion" (i.e., no bacteria as cause), but it is now possible to apply a new method—tissue culture. This technic has been a major stimulus to the recent growth of virology.

A tiny piece of living tissue is placed in a bottle or tube together with a nutrient medium and *antibiotics*. It is the advent of antibiotics, which inhibit the growth of contaminating bacteria without affecting tissue cells, that has permitted the rapid growth of this technic in many laboratories. Tissue cells are now grown in test tubes, either newly obtained from tissues or from long-maintained strains.

A particular virus will grow better in some types of cells than in others; for example, adenoviruses are more readily isolated in HeLa cells (originally obtained from a case of human cervical carcinoma) than in cells from a monkey's kidney. This is akin to the phenomena of specific differential media used commonly in bacteriology.

In addition, the changes produced by different viruses vary. For instance, poliomyelitis virus invades individual cells widely; measles produces more localized lesions, and large masses may result from the apparent fusion of cells. Indeed, a plaquelike area of destruction can be obtained by a technic recently described (15). This, too, aids in diagnosis.

Another technic of identification makes use of tissue culture. If serum containing antibodies against a specific virus is added to a tissue-culture broth, growth of the virus is neutralized. By use of this tissue-culture virus-neutralization test, a serum can be tested for its antibody content; and, through the use of known serum, unknown viruses may be identified.

A striking and colorful advance in this field has resulted from the technic of labeling antibodies with a fluorescing substance which can be seen under the fluorescence microscope. This method permits the localization of antibodies (and hence antigens) in tissues. The work of Coons and Kaplan (16) has led to methods which enable investigators to localize antigens (e.g., virus material) to the individual cells. In fact, one can determine whether virus is in the nucleus or cytoplasm or both. By virtue of the specificity of the antigen-

antibody reaction, the technic has been extended to study sites of antibody formation.

In simple terms, the tissue under study is covered by antibody-containing material, e.g., appropriate serum. Previously, the antibody was treated with a fluorescent dye. After a time the antibody is washed away. Since antigen will bind the specific antibody, fluorescent material will remain fixed only at those locations where antigen is present. Many factors, such as polymerization and pH , affect the reaction and may alter the appearance under the fluorescence microscope.

This method has been used by several workers for the demonstration of protein antigens, bacterial polysaccharides, viruses, rickettsiae, and plasma protein in tissues and cells.

Plate 4, figures 1-4, demonstrate a technic for studying the distribution of nucleic acids in normal and virus-infected cells and have been supplied by Dr. Janet S. F. Niven and Dr. J. A. Armstrong, of the National Institute for Medical Research, London (17). The material, either fixed 3μ sections or tissue-culture cells, is immersed in acid buffer (pH 2.7) and transferred to a 1:2,000 solution of acridine orange in the same buffer for half an hour. After it is washed in buffer, the specimen is mounted, sealed to prevent drying, and examined under the fluorescence microscope utilizing the blue-violet region of the spectrum. Structures containing DNA emit a bright greenish-yellow fluorescence, whereas RNA-containing material gives a flame-red color.

FACTORS INFLUENCING VIRUS ACTIVITY

We know that man has latent in various tissues throughout his body many viruses which were unknown to us a few years ago, but we do not know what many of these are doing there (18). We know that viruses can persist in their host for generations in either an infectious or a noninfectious form. They can mutate to form new strains and cause different disease symptoms. Viruses may have different effects, depending on the age, genetics, and state of nutrition and hormonal balance of the host (14).

The conversion of a virus from a latent to an active state may be effected by seasonal factors. For instance, there is a tendency for polio to occur in the summertime or for sun and wind, somehow related to the seasons, to influence the emergence of herpetic lesions. There are also hormonal factors, such as those associated with pregnancy, that influence whether or not polio will result in a paralysis.

Sometimes a bacterial infection can influence the conversion of latent virus to active virus (for example, the appearance of herpes simplex accompanying meningococcus meningitis or pneumococcus

pneumonia). Evidence has also been uncovered which suggests that a bacterial infection of the lung and possibly the upper part of the respiratory tract may cause the influenza virus, present in the latent state, to emerge in an active form. This is the reverse of what is usually believed to occur, namely, that influenza virus infections precipitate bacterial infections. It is possible that both aspects may occur (19).

RECOVERY FROM VIRUS DISEASE

During the acute phase when lesions and infected tissues are present, the concentration of virus particles is constant and often at a high level. In most virus diseases, recovery is the rule, although unfortunate sequelae may persist after some. Kinetic studies have shown that a decline in virus concentration precedes a resolution of the lesions. The mechanisms of recovery are essentially unknown and have been rarely studied. This is because laboratories tend to use fatal infections for their models.

The development of circulating antibodies has little, if any, part in recovery. Efforts to foster recovery by use of immune serum that contains antibodies have been unsuccessful. This is true even though in some instances there is a correlation between the appearance of antibodies and signs of recovery. At least there is no evidence of a causal relationship between these two phenomena. Patients with agamma-globulinemia, who are unable to produce antibodies against an infecting agent, appear to recover from some virus diseases as readily and as promptly as do normal persons (20). "Important as specific antibodies are in conferring immunity against certain virus diseases as well as in preventing migration [of virus] through the blood to uninfected tissues, there is no adequate evidence that they can alter the course of an established virus disease" (20).

We have seen that viruses are basic particles of living matter. They bear a resemblance to "genes" and produce their ill effects by altering cellular activities. How are these intracellular interferences reflected in human disease?

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In Search of a Home¹

FROM THE MUTINY TO PITCAIRN ISLAND (1789-1790)

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[With 1 plate]

SO MUCH FACT and fiction have been written about the mutiny on His Majesty's armed vessel *Bounty*, and the vicissitudes of the Anglo-Polynesian settlement on Pitcairn Island which resulted from it, that it might well seem that everything that can be said on the subject must have been long since placed on record.

This would not be true, however, of any time in Pitcairn's history, for the main chroniclers² were either primarily concerned with the Bligh versus Christian controversy or in painting an edifying picture of moral regeneration: for these purposes they were content to use, as their source material, virtually nothing except the reports or published narratives of a few naval officers, in one or two instances adding traditional information obtained from the islanders of the second generation.

This generalization has particular application to the months immediately succeeding the mutiny itself, concerning which the naval officers tell us little, and that recorded from one informant only [John Adams] long after the events themselves.

Despite its importance to any accurate understanding of subsequent Pitcairn history, this period is invariably dismissed in a few paragraphs, in which the dearth of fact may be disguised by pious observations on such themes as the alleged deterioration in Fletcher Christian's character.

Yet these months were actually packed with incidents: the first five witnessing the establishment of the settlement on Tubuai, its subse-

¹ Reprinted by permission from the *Journal of the Polynesian Society*, vol. 67, No. 2, June 1958.

² The three classics on Pitcairn history are by Barrow (1831), Murray (1853), and Lady Belcher (1870). Other standard books by Brodie (1851), Young (1894), and Shapiro (1936) add nothing fresh on the presettlement period. The only modern historian to make any significant use of new source material is Mackaness (1931), but his account of postmutiny events is naturally only incidental to his main theme.

quent abandonment and the defection of the majority of Christian's party; and the last four a voyage in the *Bounty* for those who remained that ranks with the epics of Pacific exploration, and led to the discovery of one of the principal islands in the South Seas.

That it is now possible to tell this story for the first time is due to two fairly recent discoveries (or more properly rediscoveries): the Journal of James Morrison, covering the Tubuai period, and the two narratives of Teehuteatuaonoa, or Jenny, the wife of Isaac Martin, for the voyage to Pitcairn.

Morrison's Journal was seen and cited by both Barrow and Lady Belcher, but the quotations are meager and not always scrupulously reproduced. After Lady Belcher's death the manuscript disappeared and, despite all efforts to trace its whereabouts, it was not until about 1930 that it was discovered safely deposited in the Mitchell Library at Sydney: it has now been published (Morrison, 1935).

Morrison, who was one of the *Bounty's* crew who elected to remain in Tahiti, evidently prepared this journal from notes made at the time. It is possible to verify the correctness of so many of his statements from other sources that one is left in no doubt as to its reliability, at least where his personal interests are not concerned.

Owen Rutter, in his introduction to the published edition, pays tribute to "the meticulous detail, the niceness of observation and the accuracy of the dates" in the journal; and his encomiums are well earned, for Morrison was a born observer and recorder with a genuine and sympathetic interest in the island peoples, whether on Tahiti or Tubuai. With but little training he would have made a first-rate anthropologist.

Jenny was also in her way a remarkable character. Described as "a good looking woman in her time," she went with John Adams to Tubuai and was tattooed by him AS/1789 on her left arm.³ She landed on Pitcairn as Isaac Martin's wife but was never reconciled to life there, possibly because she had no children of her own to compensate for the loss of her relatives and friends on Tahiti.

After the death of her husband, Jenny led the abortive attempt of the women to leave Pitcairn in a boat, and finally succeeded in getting away by the whaler *Sultan* in 1817. On her return to Tahiti she gave two separate accounts of her experiences; one published in the *Sydney Gazette* for July 17, 1819 (Teehuteatuaonoa, 1819),⁴ and the second in the *Bengal Hurkaru* for October 2, 1826 (Teehuteatuaonoa, 1826).⁵ She was also interviewed by Kotzebue in March 1824,

³ John Adams signed on the *Bounty* as Alexander Smith, but changed to his proper name after Folger's visit to Pitcairn in 1808.

⁴ This is an entirely different account from her later narrative, though not inconsistent with it, and is concerned for the main part with the period after the settlement.

⁵ An account dictated to the Rev. Henry Nott in the presence of Capt. Peter Dillon and communicated by the latter verbatim to the *Bengal Hurkaru*.

who said that she "spoke tolerably good English, but with a foreign accent." (Kotzebue, 1830, vol. 1, p. 225 ff.)

Jenny's narratives are not only consistent with each other, but in all cases where they can be checked from other material they have proved to be reliable. One has to remember that her interests were those of a woman, and a Tahitian, but her testimony is, in general, more trustworthy than that of Adams, who was apt to be careless with his facts even when not deliberately misleading; and she gives the best account we possess of events from the date of the final departure from Tahiti in September 1789, to Folger's discovery of the Pitcairn settlement in 1808.

In the following pages I have tried to piece together the story of the *Bounty* mutineers to the day of their landing on Pitcairn, using first Morrison and later Jenny as the main sources of information, but freely checking and amplifying by recourse to every other source that has come to light as a result of some years of delving into Pitcairn history, and 9 months spent on the island itself.

TRIAL AND ERROR ON TUBUAI

With the details of the mutiny which took place on the *Bounty* on the morning of April 28, 1789, we are not concerned here. (The best account is in Mackaness, 1931.) Nearly 170 years later the protagonists of Bligh and Christian are still engaged in apportioning the blame; an exercise which one feels at times tells us more about the personality of the writer than the characters and motives of the two opponents.

Our narrative commences as Bligh was cast adrift, 10 leagues south-west of Tofua, one of the Tonga Islands, to the sound of "Huzza for Otaheite" from the mutineers (Bligh, 1937, vol. 2, p. 122). Even these huzzas have been denied Bligh by his opponents (Barrow, 1914 ed., p. 100; Mackaness, 1931, p. 172, quoting Lady Belcher), on the grounds that no one else appeared to have heard them. His vindication, however, comes from Adams himself, who told Buffett that when the mutiny occurred "he was sleeping in his hammock, but as soon as he heard the proposal he exclaimed 'Hurrah for Otaheite.'" (Buffett, 1846, p. 2.) *

Christian now took charge and, after sounding the views of the 25 men remaining on the *Bounty*, determined to make for Tubuai, in the Austral Group, with a view to prospecting it as their possible future home, before calling at Tahiti for provisioning. Tubuai had

* See also Adams's statement to Beechey that as the launch, with Bligh on board, was being cast off "Immediately 'Huzza for Otaheite!' echoed throughout the *Bounty*" (Beechey, 1831, vol. 1, p. 76).

been discovered by Captain Cook in 1777 but no landing made, and to Christian, reading the account in the narrative of Cook's voyages in Bligh's cabin (Shillibeer, 1817, pp. 97-98), it seemed the best island to select for a retreat: he was never under any illusion as to his probable fate if he remained on Tahiti itself. The voyage took a month, the time being employed in clearing the great cabin of its breadfruit plants (except for a few kept for planting on Tubuai) and in making a uniform for all hands out of old studding sails, as Christian believed that wearing it impressed the natives. He himself moved into Bligh's cabin.

A visit of inspection.—The reception at Tubuai was anything but encouraging. The natives, seeing so few on board surrounded by so many desirable possessions and being ignorant of the power of fire-arms, commenced threatening and thieving while the ship's cutter was still examining the passage through the reef. The following day, the *Bounty* being anchored inside the lagoon, 18 girls were sent on board as decoys, "all young and handsome having fine long hair which reached their Waists in waving ringlets" (Morrison, 1935, p. 49),⁷ accompanied by 5 men who soon commenced stealing whatever they could lay their hands on. Fifty canoes filled with warriors, complete with cords for securing the mutineers when captured, came up on the other side and, much against his will, Christian was compelled to fire on them to avert a general attack. He learned later that the natives lost 11 men and a woman in this encounter, the site of which was christened Bloody Bay.

Despite this initial discouragement, Christian continued for two more days in an attempt to conciliate the islanders by leaving presents in their now deserted homes—but they were not to be drawn. His visits ashore, however, confirmed him in his opinion of the suitability of Tubuai for settlement: its size (5 miles by 3) was scarcely sufficient to attract visitors, especially when the large and more fertile island of Tahiti was only 300 miles away; it had a poor anchorage and only one passage into the lagoon navigable by ships, and its population was thought to be small enough⁸ to be propitiated into friendship or overawed into submission.

⁷ Morrison is the main authority for the whole Tubuai episode: a few subsidiary checks, however, are obtainable from the accounts of eyewitnesses given in Edwards and Hamilton, 1915, pp. 34-38; Henry, 1928, pp. 26-28; Heywood's letter reproduced in Barrow, 1914 ed., pp. 194-196; Teehuteatuaonoa, 1826; Lee, 1920, pp. 95-97; and two versions by John Adams in Beechey, 1831, vol. 1, pp. 76-80, and Moerenhout, 1837, vol. 2, pp. 288-292.

⁸ It was estimated to have been 900 in 1821, but Morrison's claim that it was 3,000 in 1789 is consistent with the other figures given in the course of his narrative. Venereal disease, which is said to have caused many deaths, was almost certainly introduced by the mutineers, 11 of whom (including Christian, Adams, Quintal, and Brown) had been treated during the course of the voyage: 9 of these after the vessel's arrival at Tahiti (Smith, 1936, pp. 216-217). In 1821-23 an epidemic reduced the population to 300 (Caillot, 1909, p. 71; Aitkin, 1930, p. 4; Montgomery, 1831, vol. 2, pp. 75-76). It has now recovered to over 1,000, partly through immigration from other islands.

Return to Tahiti.—While there was plenty of coconut, breadfruit, and banana trees, as well as taro, on Tubuai, no livestock could be found, and this determined Christian to press on to Tahiti immediately to procure a cargo of pigs, goats, and chickens, together with some women as companions and men to assist in raising crops and act as interpreters with the local population: even Christian's knowledge of Tahitian had proved insufficient for effective communication, and the others spoke hardly a word.

Despite the evidence of Fryer (Rutter, 1931, pp. 32-33) that only Stewart and Morrison (and of Adams to Beechey [Beechey, 1831, vol. 1, p. 72] that only Quintal) had any serious feminine attachments at Tahiti, it is clear that virtually every member of the *Bounty's* crew, officers as well as men, had contracted some sort of alliance with a Tahitian *taio*, or friend. And if Christian was busy with the over-all plan of settlement, Adams, in a statement made just before his death to Moerenhout, indicates what was uppermost in the minds of most of the rest: "We lacked women; and, remembering Tahiti, where all of us had made intimate friendships, we decided to return there, so that we could each obtain one" (Moerenhout, 1837, vol. 2, p. 289).

Leaving Tubuai on May 31, the *Bounty* anchored in Matavai Bay on June 6, where everyone seemed glad to see them back and evinced little curiosity as to the reason for their unexpected return. To those who inquired, Christian explained that they had met Captain Cook, who had taken Bligh and the others with the breadfruit plants and sent him back to obtain a supply of animals to stock a settlement which he was making on Aitutaki (which he described as being in New Holland!): Bligh had fortunately forbidden his crew to mention Cook's death, as had Watts before him.

This story apparently satisfied everybody and, business being brisk, by June 16 Christian had obtained some 460 pigs, 50 goats, and a number of chickens; together with a bull and a cow left by Cook, and a few dogs and cats for good measure. About 28 Tahitians⁹ also accompanied the expedition, most of them stowaways who only appeared when it was too late to return them ashore. Among them was Hitihiti, a young chief from Borabora, and an expert shot, who had sailed with Cook to Tonga, New Zealand, the Antarctic, and the Marquesas in 1773-1774.¹⁰ No one seemed worried when told that they would never see Tahiti again.

In addition, there were consorts for several of the Europeans—Mauatea (Isabella) with Fletcher Christian, Teehuteatuaonoa

⁹ According to Adams; Morrison's figure is 9 men, 10 women, 8 boys and a girl.

¹⁰ Hitihiti, an insatiable traveler, was later to accompany Bligh on his second expedition in the *Providence*, having been engaged to assist the botanist in taking care of the breadfruit (Henry, 1928, pp. 27, 31).

(Jenny) with John Adams (Teehuteatuaonoa, 1826), Mary with Thomas McIntosh (Lee, 1920, pp. 95-96)—but alas, not enough, for as Adams said later: "We did not find as many women as we wanted. Nine only came on board; and with them, eight men and about ten boys. After some ineffective efforts to persuade more women to follow us, we returned to Tubuai" (Moerenhout, 1837, vol. 2, pp. 289-290). They reached it on June 23.

Tubuai in 1789.—In contrast to the first, the second visit to Tubuai showed some promise of being a success; the natives were unexpectedly peaceful and friendly and the Tahitians, who soon mastered the local dialect, were able to facilitate good relations.

While the pre-European political organization of Tubuai has never been adequately studied, it is now possible, from Morrison and other sources, to reconstruct the main features as they existed at the time of the *Bounty's* visit.¹¹ The island was then divided into three districts, each under its chief:

- (i) Toerauetoru (now Mataura)—centered on the north coast opposite the lagoon entrance—under the chief Hiterire¹²;
- (ii) Natieva (now Taahuaia)—on the northeast coast—under Tahuhuatama; and
- (iii) Paorani (now deserted)—inland and to the east of Natieva—under Tinarou.

Tahuhuatama, who was old, had apparently handed over most of his functions to his son, Taroatohoa; as had Hiterire to Tamatoa, probably for the same reason.

Tamatoa's (or Hiterire's) domain¹³ was by far the largest and extended over Nahitorono (now Mahu) in the south, and possibly over the district of Tuporo (now Hanamea) on the west coast; or, in other words, the whole western half of the island. The dynasty had been founded by his great-great-grandfather, a chief on Raiatea (from whom the royal family on Tahiti were also descended [Morrison, 1935, pp. 73-74; Caillot, 1910, p. 439]), who had been blown there in a storm and accepted as overlord by the few people then living on the island, themselves fairly recent arrivals from Rurutu and Raivavae or, according to Caillot, 1910, p. 438, from Rimitara.

Despite marriage alliances (Tinarou was married to Tahuhuatama's sister) warfare between the districts was more or less endemic

¹¹ By far the best account of Tubuai society is given in Morrison, 1935, pp. 48-74. Morrison was an exceptionally gifted observer and it is unfortunate that his narrative was not available to Aitkin. But see also Montgomery, 1831, vol. 2, pp. 75-76; Ellis, 1831, vol. 3, pp. 383-387; Moerenhout, 1837, vol. 1, p. 149; Aitkin, 1930, *passim*, but particularly pp. 30-33.

¹² I have modernized some of Morrison's orthography. In particular, and at the suggestion of Dr. Kenneth P. Emory, of the Bernice P. Bishop Museum, the name Taroatchoa (an impossible sound in the Tubuaian dialect) is written as Taroatohoa.

¹³ Tamatoa's relation to Hiterire is obscure but he was evidently, in effect, the executive power.

until the year 1822 when Nott, the missionary, succeeded in negotiating a final peace between Tamatoa, whom he recognized as "by hereditary right, the King of the island," and Tahuhuatama. (Ellis, 1831, vol. 3, pp. 385-387.) The dynasties then appear to have united and Tamatoa IV, who was buried in the *marae* at Peetau, near Natieva, was also known as Tahuhuatama. In 1844 the island was governed by a Tamatoa, and his descendants continued to reign until the island became a French possession in 1880 (Aitkin, 1930, pp. 121-123).

Fort George.—Christian and Tamatoa were soon on terms of friendship, exchanging names and presents at a formal ceremony. Blame for the hostility shown on the first visit was put on Tinarou and his followers, who together with almost the entire population of the island had congregated at Bloody Bay when the *Bounty* appeared at the entrance to the lagoon: after the ship's departure they left again for their own territory. An epidemic which immediately followed the visit was ascribed to the wrath of the gods at their having attacked the vessel; a factor which no doubt helped to bring about the better reception experienced on their return from Tahiti.

Unfortunately, however, the only suitable land which Christian could find for his proposed settlement was 4 miles to the east of the reef passage, or well within Tahuhuatama's territory. On a visit there he was warmly greeted by Taroatohoa and offered his choice of any land he desired; names were again exchanged as a token of friendship, and indeed Taroatohoa and his family never wavered in their loyalty to Christian right up to the day of his departure.

But this action brought with it the enmity of Tamatoa, who promptly made an alliance with Tinarou, by which both agreed to boycott the Europeans, who for their part were willing and anxious to engage in barter. The supply of provisions was thus greatly curtailed, as Taroatohoa's district (the smallest of the three) could not supply enough to satisfy their requirements, and measures had to be taken to conserve the remaining ship's stores and the livestock brought from Tahiti. Nevertheless, Christian pressed on with his plans for settlement, and the *Bounty* was warped up through the shoal lagoon with some difficulty and anchored off Natieva. (See map, fig. 1.)

The land required for the proposed colony was purchased from Taroatohoa for a quantity of red feathers (Buffett, 1846, p. 2). Christian had fortunately brought a supply of these with him from Tahiti, as they proved to be much in demand on Tubuai, whereas no interest was shown in the axes and other iron tools which on most islands were preferred above all other goods except muskets. Indeed, it was hard to find any European article which the Tubuai people would acknowledge as better than their own, even cloth being rejected as

inferior to their glazed, or varnished, *tapa*, which was considered to be more rainproof. The rest of the red feathers and also some Tahiti *tapa*, which if not highly regarded proved at least acceptable, were divided up amongst the Europeans in the hope of stimulating trade in local produce.

On July 18 work commenced ashore in earnest; parties were detailed to prepare spades, hoes, and mattocks, to clear ground and plant yams, while the main body set to work on the construction of a fortress. This was to consist of walls 18 feet thick at the base, surrounded by a moat 18 feet wide by 20 feet deep crossed by a drawbridge, with four-pounders at each corner and swivel guns on each side, the whole measuring an area of 100 square yards including the moat.

Though it never reached these ambitious dimensions, Fort George, as it was called, must have been a formidable edifice even in its uncompleted state. Forty years later Moerenhout was shown the ruins (Moerenhout, 1837, vol. 1, p. 149), which were still standing in 1902, when they were examined by Seale, who wrote:

The fort consists of the ordinary military square of earth work thrown up to the heights of perhaps 6-7 feet. Its open side faces the sea, about 300 feet distant; the size of the fort is 125 feet by 120 feet [see diagram, fig. 2]. It is now overgrown with trees and brush and a native house is in the open side (Seale, MS. 1902).

Christian worked as hard as anyone on this unfamiliar task, which was intended to defend the community mainly against the natives, as shown by the fact that the side facing the shore was never completed, but also from an attack by any European vessel sent to find them. Meanwhile, his difficulties were increasing: it was hard, for instance, to maintain discipline, and the ship had hardly been anchored before Sumner and Quintal had to be punished for going ashore without leave, asserting that "we are now our own Masters." Replying that he would show them who was Master, Christian promptly put them in irons at the point of a pistol.

Native relations.—To prevent further trouble from this cause two men were allowed to sleep ashore each night (and as many as wanted could go on Sundays). Whereupon Tinarou's women set to work to entice them into his territory, where his men proceeded to take their clothes.

On July 25 a party collecting coconuts was ambushed. A few days later John Adams, clad only in a shirt, had to be rescued from Tinarou's own house. Unlike others, the girl he had followed proved a genuine friend, for she played no part in his discomfiture and indeed followed him back to the ship, fearing reprisals from her own people: one presumes this was after Jenny had left him for Isaac Martin.

Despite what he probably felt to be unjustified provocation, Christian continued his policy of conciliation. Messengers were sent to

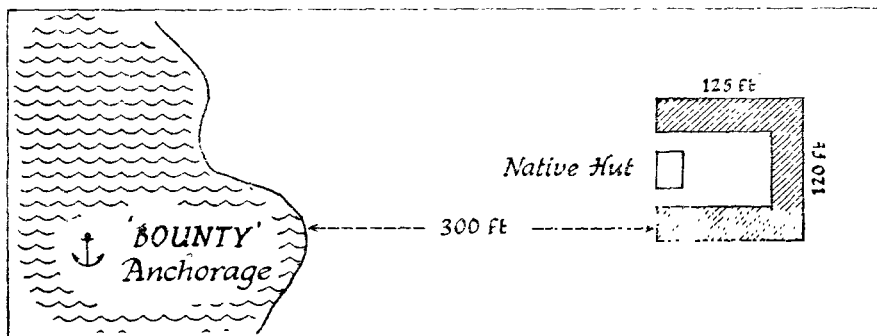


FIGURE 2.—Seale's diagram of Fort George.

Tinarou asking for the return of articles stolen and offering friendship; and it was only when these had come back rebuffed that the chief's "Household Gods" were removed and his house burnt down.

On September 2 Tinarou and his followers arrived loaded with presents and suing for peace and the return of his gods. But it was all treachery; and might well have succeeded if one of the Tahitian boys had not warned Christian in time.

Failure of an experiment.—Throughout all this excitement Tahu-huatama and his family continued to be friendly, watching the Tahitian *heiva* and showing their own dances in return. Even the friendly natives, however, would not allow their women to join the Europeans "tho they had no objection to their Sleeping with them at their own houses."

To the mutineers this was the final straw. The dénouement is well summed up by Morrison:

[They] began to Murmur, and Insisted that Mr. Christian would head them, and bring the Weomen in to live with them by force and refused to do any more work till evry man had a Wife, and as Mr. Christians desire was to perswade rather then force them, He positively refused to have any thing to do with such an absurd demand. Three Days were Spent in debate, and having nothing to employ themselves in, they demanded more Grog this he also refused, when they broke the lock of the Spirit room and took it by force (Morrison, 1935, p. 60).

Christian could do nothing in the face of this general strike, and on September 10 he was forced to call a meeting to consider future plans. After much argument, and against his strong advice, it was at length decided by 16 votes to 9 that they should "go to Tahiti and there Seperate, where they might get Weomen without force." It was agreed that those who elected to remain on Tahiti should be given arms, ammunition, and a fair share of everything on the *Bounty*, while Christian's party should have the ship "in a proper Condition to go to Sea, with Her Sails Tackle and furniture." Of the 16 who voted for Tahiti not all were actuated by the same reasons: the major-

ity were typically improvident seamen, content to enjoy today; but at least three of them, Heywood, Stewart, and Morrison, who considered that they were not implicated in the mutiny and had already planned to escape from Tubuai, regarded the move as the means by which they might eventually hope to return to England.

Christian's brother Edward, the distinguished jurist, gives a dramatic account of the scene in the great cabin of the *Bounty* when, realizing that the feeling of the meeting was against him, he made his last plea before the vote was taken:

Gentlemen, I will carry you, and land you, wherever you please. I desire none to stay with me, but I have one favour to request, that you will grant me the ship, tie the foresail, and give me a few gallons of water, and leave me to run before the wind, and I shall land upon the first island the ship drives to. I have done such an act that I cannot stay at Otaheite. I will never live where I may be carried home to be a disgrace to my family.

It is entirely consistent with Christian's character to suppose that he would have done just this. But he was not to be put to the test, for his loyal companion Edward Young, followed by seven of the seamen, gave their votes to him, with the promise: "We shall never leave you, Mr. Christian, go where you will."¹⁴

The final battle.—Both Adams and Jenny speak of a further battle. According to the former, this was precipitated by a rumor that the natives were to be exterminated and that the moat was being dug to bury them in, but in Jenny's version it was due to a conspiracy between one of the Tahitians and the Tubuai people to take the ship, murder the crew and divide their property: she adds that Christian's wife, who told her husband of the plot, never disclosed that one of her own countrymen was at the bottom of it (Beechey, 1831, vol. 1, p. 78; Teehuteatuaonoa, 1826).

A more probable reason for the fighting that occurred was, however, given by the Tubuai natives themselves, who asserted that it was due to attempts made by the Tahitians, under Christian's orders, to round up the livestock which had been landed, and in particular the 200 pigs which had been let loose on the island. These must have initially played havoc in the plantations, but the people had begun to appreciate their value, and resented their removal.

In the skirmish which ensued:

The natives were numerous, and fought with great courage, forcing the mutineers to avail themselves of a rising ground, where, with their superior skill, the advantage of fire-arms, and the aid of the Otaheiteans, who fought

¹⁴ Edward Christian in the Appendix to Barney (1794), quoted by Rutter (1931, p. 35). Christian's information was obtained, together with other evidence, from Heywood, Morrison, Muspratt, Coleman, M'Intosh, and Byrn, all of whom were present at the meeting. While, as Bligh points out, these were men of varying degrees of credit, and no indication is given as to the particular information obtained from each, I submit that in this instance, where his narrative tells if anything against his brother, we can accept it as substantially reliable.

bravely on this occasion, they at last came off victorious, with only one or two of themselves wounded, whilst the dead bodies of the Toobouaians covered the spot, and were afterwards thrown up in three or four heaps (Wilson, 1799, pp. 51-52).

In this, and the various other disputes with the mutineers, the Tubuai people were said to have lost nearly a hundred men. It can scarcely be wondered that as a result their attitude toward Europeans became so hostile that Captain Wilson, of the missionary ship *Duff*, feared to land there in 1797.

Postmortem.—It is not difficult to sense, in retrospect, that the Tubuai experiment never could have succeeded on the lines intended by Christian: a small enclave of whites subsisting as a cooperative agricultural community in the middle of a virile native society.

Even if the entire body of immigrant Europeans had possessed the humanitarian views of Christian on native rights, it would have been difficult enough to maintain friendly relations with the faction-ridden inhabitants of a closely populated island where every inch of the area was owned and the most suitable areas occupied.

But most of the mutineers had no conception at all of native rights, and even Christian, though he would not permit the forcible abduction of the island women, had to countenance the seizure of food supplies when sufficient could not be obtained by barter.

Morrison mentions that the local priests, who had great authority, were alienated at an early stage. Not unreasonably, they—

could not bear to see such superiority as the Europeans in general usurp over those who differ from themselves, and became jealous of us with respect to their religious authority to which they saw that we not only refused to take notice of but even ridiculed, for this reason they used all the Means in their power to keep the Chiefs from making Friends, thinking perhaps that if we staid in the Island, their Consequence would be lessen'd, which in all probability would have been the Case (Morrison, 1935, p. 71).

Conflict with the islanders was therefore inevitable, but it could probably have been postponed if Christian had not made the initial error of antagonizing Tamatoa, the most powerful chief on the island, by deliberately electing to settle in the territory of his rival.

Had his explorations taken him west instead of east he might well have found suitable land for his purpose in the fertile area around Tuporo, which is largely isolated by swamps from the rest of Tubuai, where he could have lived with a minimum of contact, and consequent friction—but only for a time. Christian can hardly be blamed for the implacable antagonism of Tinarou, but the domain of this chief was situated at the other end of the island. Even the much-coveted women would presumably have arrived in due course, if the mutineers could have restrained their impatience, for the unmarried Tubuai girl had considerable freedom in bestowing her favors and it is unlikely that a

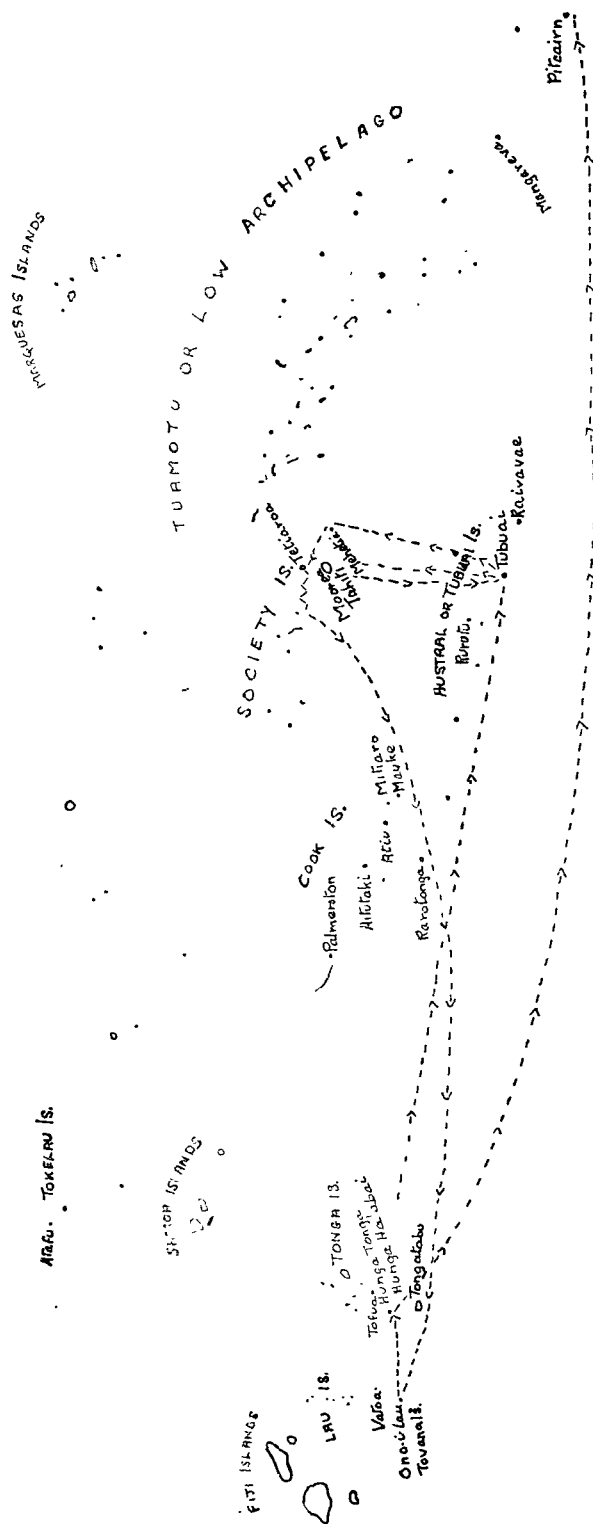


FIGURE 3.—Reconstructed track of the *Bouny*, April 28, 1789, to January 23, 1790.

sufficient number would not have come to appreciate the economic advantages of marriage with a European.

The inevitable might thus have been delayed; but it could not have been prevented. It is impossible to believe that, with the prejudiced, ignorant, and unruly men who comprised most of his followers, Christian could have maintained a respect for native customary rights over any long period; and in point of fact, several of his party did not want the experiment to succeed if it should militate against their chances of escape to civilization.

The history of other isolated Pacific islands invaded by parties of Europeans shows us that, if they stayed for any length of time, they either provoked an open conflict and were overwhelmed by numbers, as on Nauru and Abemama, or infiltrated into the villages, where they became beachcombers often barely distinguishable in their mode of life from the natives themselves. In islands not so isolated, such as Hawaii and Tahiti, this was not, of course, the case, since the constant introduction of new blood from visiting ships and the possibility of engaging in commercial pursuits enabled the formation of more stable immigrant groups.

As it was, the occupation of Tubuai did not last long enough for either of these alternatives to eventuate, but ended in failure and withdrawal after a bare 3 months, before the fort or a single home had been completed; and under the circumstances, this was probably the best ending that could have occurred. Christian had learned his lesson the hard way: that the only island on which he could safely make his future home must be one without any existing inhabitants.

Tubuai, then, was foredoomed to be a failure; but it was a necessary one, for without the mistakes made and the experience gained there, Christian would never have appreciated the minimum requirements for successful colonization. The extent to which he made use of this experience on Pitcairn is another story, but the important point here is that without it to guide his choice the chances were decidedly against his ever even thinking of selecting that particular island, out of so many possibles, for his future home.

As we shall discover from the remaining pages of this study, even with the necessary criteria now known, Pitcairn was far from being Christian's immediate or first choice. The corollary of Tubuai is thus seen to be the saga of the *Bounty*'s four months of wandering "in search of a home."

PITCAIRN AND THE VOYAGE THITHER

Before leaving Tubuai on September 17 a younger brother of Taroatohoa, called Taroamiva, came on board with two of his friends, as he considered that his life was in danger ashore owing to his friend-

ship with Christian, who accordingly agreed to take them to Tahiti (Morrison, 1935, pp. 63-64).

On the 20th they were under the lee of Mehetia, where the trade goods, arms and ammunition, wine and slops, and other articles were divided into shares. Two days later they reached Matavai Bay and, with the help of the natives, the belongings of the shore party were all landed by nightfall. Among them were the "Household Gods" of the chief Tinarou¹⁵ which later created a sensation when presented to the young Prince Tu (afterward King Pomare I) on behalf of the ship's company (Morrison, 1935, pp. 74-78).

Hitihiti, who made the presentation, and the other Tahitian men went ashore, delighted to be back, and with them went one of Taroamiva's companions from Tubuai. But during the course of the day three other Tahitian men (one was actually a Raiatean) and a boy came on board, with a number of women.

Christian also went ashore and spent some hours discussing with Heywood and Stewart the events connected with the mutiny, for which he declared himself entirely responsible. He stated that a warship would certainly be sent to look for them, whether or not Bligh succeeded in reaching civilization, and strongly advised them to give themselves up on its arrival, since neither of them had taken any part in the affair. After requesting Heywood to communicate certain matters to his family, which he felt might at least serve to extenuate his crime, he rowed to the *Bounty* and set her course out of the bay (Belcher, 1870, pp. 50-51).

The brig "Mercury."—On their arrival in Tahiti the mutineers had been told that there was now another European in the island named Brown, who had been left by Capt. J. H. Cox of the brig *Mercury*. As Brown was not seen until after Christian's departure, the latter never learnt how near he had been to discovery when all hands were busily engaged in the building of Fort George. Yet from Mortimer's narrative of the voyage it is clear that Cox sighted Tubuai on his way to Tahiti and that it was only the advent of darkness that prevented him from communicating with the islanders and, in all probability, from seeing the *Bounty* at her anchorage inside the reef:

August 9, 1789. In the afternoon, we saw the Island of Toobouai, bearing North East by East half East, distant about eleven leagues; and at eight at night passed within two miles of it. We perceived several lights on shore, and fired two guns to draw the attention of the inhabitants; but night prevented us from seeing them.

Owing to the dark, the *Mercury* got too close to the reef and, had it been calm, she would have been driven onto it by the swell "as the

¹⁵ Described as two carved images ornamented with pearl shell and human teeth, hair, and nails, and set in a nest of the red tail feathers of the tropicbird.

breakers were not a quarter of a mile from us when we wore ship" (Mortimer, 1791, p. 22).

It is intriguing to consider the infinite possibilities had Captain Cox heard of the presence of another ship at Tubuai and stopped for a sociable call, as he would assuredly have done, being in no hurry; still more of what would have occurred had the weather been calm and the *Mercury* wrecked on the island.

However, the brig passed on her way oblivious of the drama she was leaving behind, and during their stay in Tahiti the crew were much mystified by all the talk of Titreano (Christian) and Tootate (Aitutaki). The Tahitians told Mortimer that Titreano was Captain Bligh's Chief Officer who had returned in the *Bounty* without Bligh, having left him at Tootate:

This story was corroborated by Otoo and several chiefs; who further informed us that Captain Titreano had sailed but fifteen days before our arrival, and had carried several Otaheitan families with him to Tootate. Where Tootate could be, and who they meant by Titreano, we could not then conjecture (Mortimer, 1791, p. 33).¹⁶

When one considers this near miss at discovery just six weeks after the arrival of the mutineers at Tubuai, one wonders how long it really would have taken before Christian's fancied security was at an end.

Abduction by night.—To return to the *Bounty*, sailing out of Matavai Bay in the early morning of September 23. There were then 35 on board. Nine of these were Europeans:¹⁷

Fletcher Christian	Acting lieutenant.
Edward Young	Midshipman.
John Mills	Gunner's mate.
Isaac Martin	Able seaman.
William Mickoy	Do.
Matthew Quintal	Do.
Alexander Smith	Do.
John Williams	Do.
William Brown	Botanist's assistant.

With them were 6 Polynesian men, 19 women, and a little girl.

It is clear from Jenny's record (which is confirmed by Adams's statement to Captain Beechey) that, with the exception of Taroamiva and his companions "who were now become very fond of Mr. Christian and would not leave him," and probably of Christian's wife and Jenny

¹⁶ On Mortimer's return to England the significance of what he had heard was immediately realized and the authorities informed, thus providing Captain Edwards with the most plausible of the false clues that were to mislead him in his search for the mutineers a year later. (Letter from Sir Charles Blagden to Lord Palmerston, 29.6.1790, Mitchell Library phot Ab 216/1.)

¹⁷ The names are as inscribed in the *Bounty's* Muster Book and Pay Book (see Smith, 1936, p. 212.) Alexander Smith later reverted to his real name of John Adams, while Mickoy came to be known as McCoy.

herself, the natives on board the *Bounty* were in fact kidnaped against their will: blackbirding was now added to mutiny.

As it was absolutely essential to success that this time there should be no shortage of women, plans were evidently laid carefully to insure that there would not be. On arrival Christian announced to all that he would be staying at least over night. The women—many of them no doubt former companions of the Europeans—were thereupon invited on board, “with the feigned purpose of taking leave” (Beechey, 1831, vol. 1, p. 80). No doubt they came readily enough, as their sisters and mothers had been accustomed to do since the first ship touched their shores.

They were then told that the *Bounty* would be moving to Pare, Prince Tu’s district, in the morning, and taken down to supper and bed. When Christian returned on board the anchor cable was quietly cut and the ship got underway; and by the time the natives discovered that they had been tricked she was a mile outside the reefs. Even so, one of the women jumped overboard and set out for the shore: Jenny says that most of the remainder would have liked to have followed suit, but lacked the courage.

Later in the morning the *Bounty* passed close to the atoll of Tetiaroa, 26 miles to the north of Tahiti, “but not so near as to admit any of the women venturing to swim on shore there, which several of them were inclined to do, as they were much afflicted at being torn away from their friends and relatives.”

Permanent female partners were now selected—one each for the mutineers and three in all for the natives—and the ship headed for Moorea, only 9 miles from Tahiti, where a canoe came out from the shore on which the six surplus women who, as Jenny puts it, were “rather ancient,” were permitted to depart (Teahuteatuaonoa, 1826).

Let us now follow the track of the *Bounty* in search of a home, with her final complement of 28 (including the infant) on board: the future population of Pitcairn Island.

The Isles of Mendana and Quiros.—To even the most casual student of Pitcairn’s history it must have seemed curious that whereas the *Bounty* left Tahiti on September 23, 1789, she did not arrive at Pitcairn until January 15, 1790, thus taking 4 months to complete a passage of 1,200 miles which should have occupied about a fortnight.

Most authorities have been content to ignore the awkward discrepancy in dates, while the more conscientious have implied either that the *Bounty* cruised around looking for the island, apparently for some 3½ months, or else that she actually arrived there during October or early November, despite all evidence to the contrary.

In point of fact, she did neither. The evidence as to her movements during this period is admittedly not as detailed as we could wish, but

certain points can be established with a considerable degree of probability, enabling others to be deduced from them.

As we have seen, his unhappy experience at Tahiti had convinced Christian that he must seek for his future home an island which was uninhabited, unvisited, and without a harbor suitable for shipping. He would then land his belongings, including the livestock and plants, run the *Bounty* ashore and, after stripping her of everything useful, set her on fire and settle down (Edwards and Hamilton, 1915, p. 38).

This much Christian freely imparted to those left behind on Tahiti. He would have been foolish to have mentioned any more specifically where he intended to go; but actually, while he already possessed a very clear idea of what he wanted, he did not then know himself where it could be found. His alleged statement to Henry Hillbrant that he intended to investigate the suitability of Atafu, an atoll in the Tokelau Group discovered by Byron in 1765, must, I think, be regarded as a blind, since the *Bounty* never went there: if so, it turned out to be a successful one, sending the unimaginative Captain Edwards, in H.M.S. *Pandora*, on a wild goose chase which took him thousands of miles in the wrong direction (Edwards and Hamilton, 1915, pp. 40, 45-46). Once Edwards had passed so far to the westward it was a moral certainty that he would not attempt to beat back against the trades to renew his search.

From the two accounts left by Jenny and three separate statements made by Adams, none of which contains any major inconsistencies, it appears that after dropping the women off at Moorea it was proposed to prospect the Marquesas Islands, to the northeast of Tahiti, for a suitable location for the intended settlement. While this suggestion was being debated, the *Bounty* was kept on various tacks in the hope of sighting some uncharted and uninhabited island, apparently in the vicinity of Tahiti itself (Beechey, 1831, vol. 1, p. 80; Moerenhout, 1837, vol. 2, p. 292).

Instead of settling in the Marquesas, however, Adams told Folger in 1808 that they "went in search of a group of islands, which you may remember to have seen on the chart placed under the head of Spanish discoveries. They crossed the situation of those imaginary isles, and satisfied themselves that none existed" (Folger, 1819, p. 265).

This is, in fact, what I believe they did. It must be remembered that in 1790 the identification of the discoveries of Mendana and Quiros were still not recognized in England and they were generally considered to lie well to the west of their actual position. To quote Beaglehole:

Dead reckoning had led Mendana to put his Western Isles 1,700 leagues from Peru; they were in reality 2,000 miles more distant. It was natural that by 1646 they should be incorporated into the Marquesas, that in the passage of time their supposed longitude should vary from 2,400 to 7,500 miles west of

Peru and even their latitude from 7° to 19° S. It was natural that Carteret should sail five degrees west of the position attributed to them in his own day and, not meeting them, utter his unbelief (Beaglehole, 1934, p. 384).

The discovery of Rarotonga.—Unfortunately for us, Jenny was not particularly interested in the route taken by the *Bounty* and only mentions a visit to an island when it is associated with some incident that happened to excite her attention at the time. She describes how they sailed before the wind to the westward until—

After many days a small island was discovered called by the natives Purutea. A canoe came off bringing a pig and cocoanuts with them. One of the natives ventured on board and was much delighted by the pearl-shell buttons on Captain Christian's Jacket. The Captain in a very friendly manner gave the man the Jacket. He stood on the ship's gunwale showing the present to his countrymen when one of the mutineers shot him dead. He fell into the Sea. Christian was highly indignant at this. He could do nothing more, having lost all authority, than reprimand the murderer severely: the other natives in the canoe immediately picked up their murdered companion, placed the body in the canoe and paddled towards the shore with loud lamentations.

After several days more, saw one of the Tongataboo or Friendly Islands . . . (Teehuteatuaonoa, 1826).

Meager though this account is, it still enables us to establish, first, that Christian sailed west from the Society Group until he reached the Tongan Archipelago (we shall see later that the island visited there was most probably Tongatapu itself), and second, that he sighted at least one island between the two groups. A glance at the map, furthermore, will show that his route should have taken him right through the southern Cook Islands, the obvious inference being that Jenny's Purutea must have been one of them.

We do not have to be content with Jenny's unsupported testimony for this inference, however, as there is confirmatory evidence from one of the Cook Group in the traditions of the islanders themselves (Gilson, MS., 1952, pp. 14–16).

This evidence comes from Rarotonga where the missionary John Williams, on his first visit there in 1823, was surprised to find that news of Captain Cook's visits to Tahiti had already been brought by a party of men who had drifted from that island in a canoe, as well as by a mysterious woman (Williams, 1838, p. 106).¹⁸ Impressed by what they had heard, the Rarotongans petitioned the Gods to grant them a similar visit:

O, great Tangaroa, send your large ship to our land; let us see the Cookees. Great Tangiia, send us a dead sea, send us a propitious gale, to bring the far-famed Cookees to our island, to give us nails, and iron, and axes; let us see these outriggerless canoes.

¹⁸ Her means of conveyance is not stated, but she may have been one of the two Tahitian women who came to Rarotonga with Goodenough (Gill, 1911, p. 193).

Williams records that—

Not very long after this, a large ship did actually arrive; and from the description the natives gave me of her, I have no doubt but that it was the *Bounty*, after she had been taken by the mutineers. This vessel did not anchor, but one of the natives took his little canoe, and summoning all his courage, ventured to go on board. On returning to the shore, he told his astonished countrymen that it was a floating island; that there were two rivers of water flowing on it; that two large *taro* plantations, with sugar-cane, bread-fruit, and other trees, were growing there, that the keel scraped the bottom of the sea; for he dived as deep as man could go, and could not see its termination. I account for these singular statements, by supposing that the pumps were at work while the man was on board, which he mistook for rivers, or streams, and that the two plantations, bread-fruit trees, etc., were the large boxes which were fitted up throughout this vessel for those exotics, which it was the specific object of the *Bounty* to convey from Tahiti to the West Indies. From this vessel was obtained a pointed piece of iron, about two feet six inches in length, which the natives immediately dedicated to the gods . . . (Williams, 1838, pp. 201–202).¹⁹

An even more detailed account of this visit was later given by Maretu, a local authority on the early history of the island, who informed Dr. Wyatt Gill that Goodenough, who called at Rarotonga during the year 1814, was not its discoverer, since before him—

There came here a very large ship, but the people did not land. Two canoes went off to that ship, and bartered some goods from the white people, amongst them the *Anae*; they purchased these things with fowls, coconuts, and bananas. As they left, a man named Maia stole a large box from the ship, and in it was found the orange and the *motini*. Makare was the name of the captain. One of the chiefs who went on board, named Tamarua, reported that they had *taro* swamps and young banana trees, besides young bread-fruit trees and many packages of *anae*, with stones also. They were wild with astonishment at that ship. It was from thence we obtained the first oranges, whilst Kaputini procured a *mautini* from there (Gill, 1911, p. 192).²⁰

We have the authority of Stephen Savage, the Rarotongan scholar and translator of Maretu's statement, that Makere is the Maori transliteration of McCoy; *motini* (or *mautini*) is the pumpkin and *anae* a species of fern, though it may also have had some other meaning in Maretu's day. The "stones" referred to were thought to have been iron implements.

¹⁹ Basil Thomson, in quoting this passage, is apparently so concerned at its implications that he flatly accuses Williams of error, arguing that "the tradition must have referred to Bligh's visit to Aitutaki before the mutiny when the decks were encumbered with bread-fruit, for we know that the first thing the mutineers did after setting their captain adrift was to throw all the bread-fruit plants overboard, and that they steered direct for Tahiti" (Edwards and Hamilton, 1915, pp. 40–41, footnote 2). A further example of the reluctance of historians to accept evidence tending to discredit the time-hallowed theory that the *Bounty* went straight from Tahiti to Pitcairn is mentioned in footnote 25.

²⁰ A MS. translation of Maretu's autobiography in the Library of the Polynesian Society states that the Rarotongans also obtained braces and belts from the ship, and recognized the *mato* (a tree that grew on their island) among the vegetation on board. No one came ashore "because of the rain" (Maretu, MS., 1949, p. 4). For Goodenough's visit, which Gill wrongly thought had occurred in 1820, see the *Sydney Gazette* for Oct. 22, 1814.

Both Williams and Wyatt Gill were under no doubt that Rarotonga had been visited by the *Bounty*, though not having the evidence we now possess Gill concluded that she called there immediately after the mutiny and on her way to Tahiti (Gill, 1911, p. 192).²¹ Gosset, who lived in the Cook Islands from 1899 to 1904, found a definite tradition among the older generations in Rarotonga that the *Bounty* had called; and Pa Maretu, then chief of Ngati-Tangiia, assured him that the first orange trees on the island grew from the seeds of the fruit found in the stolen box (Gosset, 1940, pp. 9-10).

But even if we admit the authenticity of the tradition of a ship's call, was that ship necessarily the *Bounty*? I suggest that an analysis of the evidence, especially that relating to the cargo on board, indicates that it was.

In the first place, an exhaustive search has established that only two vessels reported sighting Rarotonga before Goodenough's visit, and both passed the island within a few months of the event.²² Of these, one had no contact with the shore, while the other was known to be short of provisions and would certainly not have given the appearance of a floating horticultural exhibition.

In fact, even in the unlikely event of some other vessel calling and omitting to record the visit is it conceivable that she would be carrying a cargo of growing taro tubers, young banana shoots, and breadfruit trees, obviously plant material for an agricultural settlement on some South Sea (or at least tropical) island? But the *Bounty* was: for Morrison tells us that when Christian left Tahiti she was full of live-stock "together with plants of all the kinds that are Common in these Islands" and Jenny reports that on her arrival at Pitcairn the settlers set to work immediately planting the yams, taro, bananas and *aute*²³ which they had brought with them (Teehuteatuaonoa, 1819). That they did not need to plant the breadfruit trees, which Adams says they had also kept on board from Bligh's plants, was only because there were found to be plenty already growing on the island.

As regards the name McCoy,²⁴ although this is not a common name it can scarcely be regarded as sufficient proof of the visit in itself, but is valuable as supporting evidence. The fact that McCoy (one of the most refractory of the able seamen on the *Bounty*, who had caused trouble to both Bligh and Christian) was believed to be the captain is, of course, of no significance. In the intense excitement which must have prevailed on that brief visit to the first European ship ever seen,

²¹ Aaron Buzacott, missionary on Rarotonga from 1828 to 1857, thought the same (Calvin, 1953, pp. 49-50).

²² The *Endeavour* (September or October 1813) and the *Seringapatam* (May 1814).

²³ The paper mulberry (*Broussonetia papyrifera*), from which the Tahitian brown cloth was made.

²⁴ The name is spelled Mickoy in the *Bounty's* Muster Book and Pay Book, and by Bligh in his Log; elsewhere one finds it spelled variously M'Coy, M'Koy and McKoy. His descendants, however, have called themselves McCoy, and this has become the accepted usage.

it is not surprising if a mistake was made on this point: McCoy was presumably the man with whom the informant spoke; was quite possibly in charge of the watch at the time; and may well have conveyed the impression that he was in charge of the vessel.

The *Bounty*, then, is the only ship believed to have visited Rarotonga prior to 1820 without being in a position to have reported, and thus taken the credit for, such an important discovery; the only ship likely to have carried such an unusual cargo; and, with a lower degree of probability, the only ship with a European named McCoy on board. When one adds that, as we now know, her route would logically have taken her through the area in which the island is situated, it is hard to resist the conclusion that Christian was the rightful discoverer of Rarotonga.

There remains the problem of Purutea. This island was almost certainly one of the Cook Group, though it cannot be found among the few local place names recorded, but the incident mentioned by Jenny is not recounted either by Williams or Maretu. All one can say, therefore, is that Purutea could have been Rarotonga; but that from its position it could also have been Mauke, Atiu, or Mitiaro.

It was not Palmerston Island, 270 miles to the northwest of Rarotonga, where Captain Edwards found a yard marked "Bounty's Driver Yard" and some spars with "Bounty" written on them, from which he at first concluded that the vessel had called there (Edwards and Hamilton, 1915, pp. 9, 43-44, 124). But as these were all lying on the beach at high-water mark, and worm-eaten from long immersion in the sea, they were clearly the spars lost while the *Bounty* was being warped up through the shallow lagoon at Tubuai when, as Morrison tells us: "After we had got about halfway, it became necessary to lighten the ship, by starting the Water; but that not being sufficient the Booms and Spars were got out and Moord at a Grapnel, but it coming on to blow fresh they went adrift and we saw them no more . . ." (Morrison, 1935, p. 55).

Normal set of wind and current could have easily taken them northwest to Palmerston.

Tongatapu.—We have seen from Jenny's narrative that from the Cook Group the *Bounty* continued to sail west until, several days later, she reached one of the Friendly Islands, where the mutineers traded with the Tongans for pigs, chickens, and yams.

It is fortunately possible to identify, with a considerable degree of probability, the actual island at which they called, since Jenny mentions that the natives told them that "Totee (Captain Cook) had been there, and that the horned cattle left by him were living" (Teehu-teatuaonoa, 1826).²⁵

²⁵ Mackaness, who cites Jenny, omits from his quotation the passages referring to the visit to Tongatapu, at the same time repeating the story of the *Bounty* sailing direct from Pitcairn (Mackaness, 1931, pp. 209-211).

Cook did leave cattle in the Tongan Group, as Jenny says; on the island of Tongatapu itself, and nowhere else in the Western Pacific. And in leaving them he pointed out that "there were no such animals within many months sail of their island . . . that therefore they must be careful not to kill any of them, till they had multiplied to a numerous race" (Cook, 1785, vol. 1, p. 303. This was in 1777).

There is every reason, therefore, to believe Jenny's account of the *Bounty's* visit to Tongatapu, where she says that they stayed 2 days. She is a reliable witness; and on all occasions on which it has been possible to check statements made in her two narratives they have proved to be both accurate and consistent. Furthermore, it is unlikely that she would have had any motive for inventing this particular story, with all its circumstantial detail; or, indeed, that she would have possessed the knowledge to do so.

The only evidence against regarding Tongatapu as the island called at comes from a passage in the recently discovered Pipon MS., in which Adams informs Captain Pipon that Fletcher Christian—

. . . after having left Otaheite the last time (for he visited Anamooka, one of the Friendly Islands, after his desertion from his duty, and disobedience to his Captain, not finding the reception he expected there, or rather that his plans could not be carried into execution without fear of detection) returned to Otaheite with a feigned story, which the Islanders readily gave ear to, of having met Captain Cook, who had sent him, "Fletcher," for a supply of provisions . . . (Pipon, MS., 1814).²⁸

While this involved and ambiguous sentence might conceivably be considered as confirmation of the *Bounty's* visit to the Tongan Group after the mutiny, I do not believe that we can legitimately regard it as such, for the wording suggests that Pipon (either through a misunderstanding or being misinformed by Adams) has telescoped the vessel's call at Nomuka (then known as Anamooka) just prior to the mutiny and the visit to Tubuai which succeeded it. Much of the other information obtained by Pipon from Adams is similarly garbled.

It would seem, therefore, that Christian went in search of his islands by a route south of the track taken by previous discoverers on their way from Eastern to Western Polynesia; the exceptions, Cook in 1777 and Cox in 1789, who were both sailing in the opposite direction, had gone even farther to the south.

This is not surprising, for it is logical to suppose that Christian would have taken a new route, since he knew that none of the Spanish islands, or any others suited to his purpose, lay in the areas already traversed, and to have gone farther north still would have taken him

²⁸ The Pipon MS. has never been published in its entirety, though short extracts from it have been quoted by Barrow and others. The editor of the version published in the *United Service Journal* (1834, pp. 191-197) has unfortunately omitted many of the more important passages relating to Christian, including the one quoted. On this point see Mackaness, 1931, pp. 216-219.

into the Tropics, not a propitious locality for permanent European settlement. It is interesting to note, however, that he was now almost back where he had started, for Tongatapu is less than 100 miles from Tofua, the island off which the mutiny had taken place 7 months before.

The Lau Islands.—After leaving Tongatapu the course was still set to the westward for “a few days,” after which they came upon a small, low island:

Here Christian proposed to stop. The boat was sent on shore to ascertain whether the island was inhabited or not. Before they had time to land people were seen on the beach. After landing and remaining awhile on shore the boat returned to the ship with the news. Had this been an uninhabited island, Christian would have destroyed the ship and stayed there. Finding the inhabitants were numerous they sailed away that night to windward (Teehuteatuaonoa, 1826).

This would appear to be the “low lagoon island, which they call Vivini, where they got birds, eggs and cocoa nuts,” mentioned in Jenny’s first narrative.

The only small, low islands lying a few days sail to the westward of Tongatapu are the Southern Lau Group of Fiji, distant approximately 220 miles and consisting of Vatoa, Ono-i-Lau, Tuvana-i-tholo, and Tuvana-i-ra. Of these only Vatoa and Ono-i-Lau possess lagoons, so that Vivini must have been one or other of these islands.

The name cannot be traced anywhere in the Pacific: but this means little since most local place-names, including those on Vatoa and Ono-i-Lau, have never been published, and in any case it could be merely the Tahitian rendering of a name given by the mutineers.

Its position rather favors Ono-i-Lau (lat. 20°39' S.), as lying nearest to the parallel of 21° S. on which Christian appears to have been sailing since he left Rarotonga, and it had, at least in recent years, the larger population (586 as against 171, in 1936). On the other hand, Vatoa is the lower (209 feet as against 370 feet) and has a less intricate lagoon entrance for boats.

The evidence, however, is too inconclusive for us to say with any confidence which of the two islands was visited by the *Bounty*; a pity because, while Vatoa was seen by Cook in 1774, Ono-i-Lau is not believed to have been discovered until 1820, when Bellingshausen sighted it.²⁷

Pitcairn’s Island.—It was now toward the end of November; 2 months had passed since leaving Tahiti and the mutineers must have

²⁷ It appears that of Fiji’s historians only Sir Everard Im Thurn has discovered Jenny’s narrative and realized its significance. In his introduction to Lockerby’s *Journal*, Sir Everard quotes the appropriate portion (from the *Bengal Hurkaru*) and goes on to state that, in his opinion, it “suggests with much probability, that the *Bounty* herself, after the mutiny and her subsequent return, under Christian, to Tahiti, actually touched at a Fijian island, and that this island, rather than Pitcairn, might have become the hiding place of the mutineers” (Im Thurn and Wharton, 1925, pp. XVIII–XIX).

felt no nearer finding their future home than they had been when they started. As for the Isles of Solomon, they had proved as elusive as ever and Christian would have probably agreed cordially with Byron 25 years earlier, who gave up the search for them at Atafu in the Tokelaus (6° farther east) with the remark that "the only person who has pretended to have seen them is Quiros, and I doubt whether he left behind him any account of them by which they might be found by future navigators" (Kerr, 1811-24, vol. 12, p. 94).

At all events, further search to the west was abandoned in the Southern Lau Group and the *Bounty* headed for the first time toward Pitcairn. It would be interesting to know at what stage of the voyage Christian began to consider this island as a possibility; but one can imagine him seated in Bligh's cabin anxiously thumbing through the many volumes of voyages known to have been on the shelves (Shillibeer, 1817, pp. 97-98).

Among these was an edition of *Hawkesworth's Voyages*, published in 1773, which contained this brief description by Carteret of his discovery, made in 1767:

We continued our course westward till the evening of Thursday, the 2nd of July, when we discovered land to the northward of us. Upon approaching it the next day, it appeared like a great rock rising out of the sea: it was not more than five miles in circumference, and seemed to be uninhabited; it was, however, covered with trees, and we saw a small stream of fresh water running down one side of it. I would have landed upon it, but the surf, which at this season broke upon it with great violence, rendered it impossible. I got soundings on the west side of it, at somewhat less than a mile from the shore, in twenty-five fathoms, with a bottom of coral and sand; and it is probable that in fine summer weather landing here may not only be practicable but easy. We saw a great number of sea-birds hovering about it, at somewhat less than a mile from the shore, and the sea here seemed to have fish. It lies in lat. $20^{\circ}2'$ south: long. $133^{\circ}21'$ west. It is so high that we saw it at the distance of more than fifteen leagues, and it having been discovered by a young gentleman, son to Major Pitcairn of the marines, we called it PITCAIRN'S ISLAND (Hawkesworth, 1773, vol. 1, p. 561. For a statement by Adams that Christian saw the account see Beechey, 1831, vol. 1, p. 80).

The latitude given in this account is an obvious slip, for in his chart of Pitcairn Carteret states it to be in $25^{\circ}02'$ S. and $133^{\circ}30'$ W.: its actual position is $25^{\circ}04'$ S. and $130^{\circ}16'$ W., or nearly 200 miles to the east of Carteret's reckoning. Cook had passed close by, without sighting it, on his first voyage; and had again missed it on his second by being compelled, through an outbreak of scurvy, to make for Tahiti when only a few miles to the westward (Beaglehole, 1934, pp. 283, 322).

To Christian the description of the high, tree-covered island, with its running water, apparently uninhabited and clearly difficult of access, must have appeared the solution to his troubles. But two more months were to pass before they sighted it; a weary period of tacking in the teeth of the southeast trades during which, Jenny says, "all on

board were much discouraged; they therefor thought of returning to Tahiti."

In one account Jenny speaks of no land being seen throughout the period, but in the other of passing "between two mountainous islands, but the wind was so strong they could not land" (Teehuteatuaonoa, 1819): this would presumably be when returning through the Tongan Archipelago, the islands being most probably Hunga Ha'abai and Hunga Tonga, some 30 miles to the north of Tongatapu and a bare mile apart.

Moerenhout, writing of Mangareva Island (300 miles to the northwest of Pitcairn) after his visit there in 1834, says:

The Indians speak of a vessel which long preceded that of Captain Beechey. They even show the spot where the ship anchored and remember having had a dispute with the crew in which several of the natives were killed. This appears the more probable in that, before the arrival of the *Blossom*, the people of Mangareva had a knowledge of iron and cultivated water-melons, which are not indigenous to their island (Moerenhout, 1837, vol. 2, pp. 322-323).

As no one has been reported to have landed at Mangareva before Beechey's visit in 1825 in H.M.S. *Blossom*,²⁸ Hall has posited the suggestion that the *Bounty* called there en route to Pitcairn, leaving watermelon seeds and iron tools (Hall, 1935, pp. 37-39). If this had been so, however, I think that we should have heard of it, if not from Jenny then from John Adams, who knew that Beechey was going from Pitcairn in the direction of Mangareva and would surely have mentioned the fact had he been there himself. The iron and watermelon seeds can best be ascribed to the sealers and whalers known to have been in the area from 1817, and even earlier. No less than 19 ships are known to have called at Pitcairn before H.M.S. *Blossom*, while several others were sighted but did not stop: is it reasonable then, to suppose that not one ever visited an island so near?

Much has been conjectured also on the supposed feat of finding such an incorrectly charted island as Pitcairn, and some authorities claim that Christian must have spent weeks in looking for it. But in point of fact, there should have been little difficulty, since Christian had only to run along the latitude, which was approximately correct, until it was sighted.

This was on the 15th of January, 1790²⁹; in the evening, when the setting sun would have lighted up the heights of Goat-house Peak and the Ridge. It was boisterous weather, though midsummer, and the seas so rough that it was 3 whole days before they could attempt a landing (Teehuteatuaonoa, 1826).

²⁸ Wilson, of the missionary ship *Duff*, the discoverer of Mangareva in 1797, only passed by the island.

²⁹ This date is calculated from statements made by Jenny and Adams. The *Bounty* was burnt 8 days later, on January 23.

One can readily picture the tense expectancy of those last days off the island, as the little group of Europeans and Polynesians stood at the rail of the *Bounty*, speculating on its suitability for permanent settlement. Even from the sea they could discover coconut palms and breadfruit trees among the prevailing *miro* and *purau*, sure signs of former, if not present, inhabitants; it was resolved, therefore, to send a well-armed prospecting party to make an inspection before contemplating any major disembarkation.

As soon as the weather had moderated enough for a landing to be attempted, the boat was lowered and Christian, Brown, Williams, McCoy, and the three Tahitians rowed through the surf to the shore at what is now called Tedside, the alternative rough-weather landing place on the western coast. The ship then stood out to sea.³⁰

Two days later Christian was again taken on board. He returned, says Adams, "With a joyful expression such as we had not seen on him for a long time past" (Moerenhout, 1837, vol. 2, p. 293). The island had, in fact, exceeded his most sanguine hopes: in its fertility, its beauty, its temperate climate and, above all, in its now demonstrated inaccessibility, Pitcairn was ideal for his purpose. And, in addition, the race which had planted it ready for their use had apparently died out or departed, for the traces they found of their occupation were all old.

The search was over: during the nine eventful months since the mutiny on the *Bounty*, Christian and his followers had seen much and done much; they had attempted the colonization venture at Tubuai, which even if a failure had given them invaluable experience and a knowledge of the necessary conditions for future success; they had crisscrossed the South Pacific three times, visiting the Society, Austral, Cook, Tonga, and Fiji Groups; they had discovered the important island of Rarotonga; they had searched in vain for the lost islands of Mendana and Quiros; they had acquired wives and an entourage; and now, after sailing over 7,800 miles from the day they left Bligh and Tofua, the mutineers had found their future home and the *Bounty* her last resting place.

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³⁰ While they were away John Mills is said to have made an unsuccessful attempt to induce his companions to maroon them and return to Tahiti (Bennett, 1840, vol. 1, p. 46).

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The Chinook Sign of Freedom: A Study of the Skull of the Famous Chief Comcomly

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[With 6 plates]

November 7th [1805]. . . . We had not gone far from this village [Wahkia-cums] when the fog cleared off, and we enjoyed the delightful prospect of the ocean—that ocean, the object of all our labors, the reward of all our anxieties

November 20th. . . . As we went along the beach we were overtaken by several Indians, who gave us dried sturgeon and wappatoo-roots, and soon met several parties of Chinooks returning from the camp. When we arrived there we found many Chinooks; two of them being chiefs, we went through the ceremony of giving to each a medal, and to the most distinguished a flag. Their names were Comcommoly and Chillahlawil.—From *History of the Expedition under the Command of Lewis and Clark*, by Elliott Coues (1893).

. . . The process by which [head] deformity [among the Chinooks] is effected commences immediately after birth. The infant is laid in a wooden trough, by way of cradle. The end on which the head reposes is higher than the rest. A padding is placed on the forehead of the infant, with a piece of bark above it, and is pressed down by cords, which pass through holes on each side of the trough. As the tightening of the padding and the pressing of the head to the board is gradual, the process is said not to be attended with much pain. The appearance of the infant, however, while in this state of compression, is whimsically hideous, and “its little black eyes,” we are told, “being forced out by the tightness of the bandages, resemble those of a mouse choked in a trap.”

About a year's pressure is sufficient to produce the desired effect, at the end of which time the child emerges from its bandages a complete flathead, and continues so through life. It must be noted, however, that this flattening of the head has something in it of aristocratical significancy, like the crippling of the feet among Chinese ladies of quality. At any rate, it is a sign of freedom. No slave is permitted to bestow this enviable deformity upon his child; all the slaves, therefore, are roundheads.—From *Astoria; or, Anecdotes of an Enterprise Beyond the Rocky Mountains*, by Washington Irving (1849).

THE great majority of the North American Indians either died off, were killed, or became racially admixed and acculturated before they could be studied by physical anthropologists. This is particularly true of the Indians originally occupying the coastal regions of the United States, which naturally were the first parts settled. Thus, today much of our knowledge of the physical characteristics of these Indians has come from studies of skeletons. Yet rarely are skeletal remains identifiable beyond such general attributes as sex, age, and cultural affiliation. An exception is the skull of Chief Comcomly, subject of the present study. This specimen has unusually good documentation and offers evidence of a distinctive culture trait, namely, intentional head flattening. Emphasis will be placed on the deformity, because this is a study in physical anthropology; but the documentation is very valuable, as will become apparent. The above quotations, besides supplying the title and the first mention of Comcomly, are notable examples of the available documentation concerning this chief and the customs of his tribe. It is regrettable that space limitations will not permit the inclusion of many other such interesting and pertinent statements.

The writer is indebted to Stanley P. Young, recently retired from the United States Fish and Wildlife Service, Department of the Interior, for calling to his attention the existence of Comcomly's skull; to the Clatsop County Historical Society, Inc., of Astoria, Oreg., Otto Owen, president, and in particular to its corresponding secretary, Burnby M. Bell, for the loan of this skull; and to the Academy of Natural Sciences of Philadelphia for the loan of skull No. 462 of the Morton Collection (John K. Townsend's Chinook "chief").

HISTORICAL BACKGROUND

When in May 1841 Charles Wilkes, commander of the United States Exploring Expedition, visited the remnants of Astoria, the Astor establishment at the mouth of the Columbia River, he was taken to see the "tomb" of the Indian chief Comcomly.¹ Known as "the hospitable chief," Comcomly had been the leader of the Chinook tribe when Lewis and Clark arrived in the area in 1805; he had died during an epidemic in 1830 at an estimated age of 65 years.² In reporting his visit Wilkes (1845, vol. 4, p. 343) gave a drawing of the "tomb" (pl. 1),³ and added, "The chief's skull, it is believed, is in Glasgow,

¹ Many different spellings of the name appear in the literature. The spelling used in the *Handbook of American Indians* (Hodge, 1907, p. 329) has been followed here, being at the same time a simplified form of that given by Lewis and Clark (see epigraph).

Other spellings include the following: Com-com-le, Te-cum-le, Comcomil, Com-com-moley, Kum-kumly, Kom-komle (see Lewis and Murakami, 1923, footnote 46 on p. 74). Sometimes the initial "m" is changed to "n."

² This is based on Scouler's (1905) estimate of Comcomly's age in 1825 as 60 years.

³ Three years later Father De Smet also visited the "tomb," being perhaps the last to record a visit thereto (see Chittenden and Richardson, 1905, pp. 442-443).

having been long since removed by Dr. Gardner [sic].” Actually, Dr. Meredith Gairdner, physician of the Hudson’s Bay Company at Fort Vancouver, had removed the skull in 1835, only 6 years before, and he himself had died of tuberculosis in the Hawaiian Islands the following year. Also, the skull was not in Glasgow, but in the Haslar Museum at the Royal Naval Hospital near Portsmouth, England, where it had been placed in 1838 by its recipient Dr. (later Sir) John Richardson, the famous explorer of the American Arctic and the founder of the museum. These facts are to be found in the museum’s records in the following form:

Copy of correspondence relating to the skull of Comcomly

Presented by Dr. Richardson

Skull of Comcomly, Chief of the Chinook Nation inhabiting the Country at the mouth of the Columbia in North West America. It was sent to Dr. Richardson by Dr. Meredith Gairdner a young naturalist of great talent, known to the scientific world by several able papers on mineral and other subjects,* but who died prematurely of consumption at Oahu in the Sandwich Isles, shortly subsequent to the date of his letter of which the following is an extract.

OAHU, SANDWICH ISLES, 21st. November 1835.

My Dear Sir,

I wrote to you from the Columbia in Sept. last and merely add these few lines to inform you that the accompanying head in a small box is that of Comcomly the old Chief of the Chinook Nation at the mouth of the Columbia, who died four or five years ago. You may have heard of this character, for he is mentioned in most of the narratives relating to the Columbia. By his ability, cunning or what you please call it, he raised himself and his family to a power and influence which no Indian has since possessed in the districts of the Columbia below the first rapids 150 miles from the sea. When the phrenologists look at his frontal development what will they say to this? If I return to the Columbia I will endeavour to procure you the whole skeleton. I would readily have done so now were it not for my weak state of health; as it was my exertions in procuring the head cost me a severe paroxysm of haemoptysis. The mummy like state of preservation which dead bodies of the Indians attain is curious. After death they are not embowelled or rubbed with oil or any gummy substances; they are merely sometimes painted with ochre and water and wrapped in several folds of blankets; they are then deposited in a canoe which is placed on a stage elevated about 6 or 7 feet from the ground; they here attain the most perfect state of exsiccation, though very imperfectly sheltered from the weather (the climate is very wet for six months in the year). After remaining in this position for 3 or 4 years, as may be, the relatives remove them from the canoe and deposit them in the ground. I assure you no small resurrectionary labour was necessary to get at Comcomly’s.

I remain,

Dr. Sir,

Yours Sincerely,

MEREDITH GAIRDNER.

* The Catalogue of Scientific Papers of the Royal Academy of Science (London) lists five papers under Gairdner’s name, of which three report geographical and meteorological observations made in America.

The original has the following device at the end of the letter:

Comcomly's history is partly given in Ross Cox's travels and his fame has been more generally spread since his skull reached England by Washington Irving's pleasing compilation of "Astoria." Comcomly was one-eyed. His head reached England in the dried state mentioned by Dr. Gairdner, but with the features greatly distorted and pressed to one side. The moisture commenced to become very offensive in about 5 to 6 months, notwithstanding a liberal application of corrosive sublimate; it was macerated and the brain removed.

Haslar Museum
22nd. June 1838

(Vide letter book 1827-1847)

The true location of Comcomly's skull and the existence of the letter from Gairdner covering the transmission to Richardson were made known in 1939 by A. G. Harvey. But in 1940, during the bombing of England, the Haslar Museum was destroyed, along with most of its collections. Comcomly's skull (but unfortunately not his lower jaw) was one of the very few historic relics saved. Then, late in 1953, after extensive correspondence between the Haslar Museum authorities and Burnby Bell of the Clatsop County Historical Society of Astoria, Oreg., the skull was given to the latter institution and thus returned to the vicinity of the original "tomb."

If the odyssey of this skull had ended here, the present addition to the scientific record might not have been written. In 1956 the skull made still another trip away from its original resting place. This time, with the approval of the Council of the Chinook Nation, it crossed the North American Continent to the Smithsonian Institution, where it remained long enough for an anthropometric study to be made. Since that time the skull has been on display in the Historical Society's museum in Astoria. So far as is known, this is the only Chinook skull which can be attributed to a known personage. Indeed, skulls of known Indians are very rare, much less those of historically important Indians.

At this point, and in spite of the full history here outlined, the question might be raised as to how one can be sure that the skull studied at the Smithsonian in 1956 is the same one which Gairdner removed from the grave at Astoria in 1835, or indeed was that of Comcomly to begin with. This is a proper question and in line with what a court would wish to know about the sequence of possession of material evidence. Retracing the sequence in this instance we may assume that Gairdner was certain of the identity of Comcomly's grave. After all, Comcomly had been dead only five years and at first, following Chinook custom, his body had been in an elevated canoe. "Later, for greater security, his body [had been] taken out of the canoe by relatives and placed in a long box in a lonely part

of the woods" (Lewis and Murakami, 1923, footnote 46, pp. 76-77).⁵ Gairdner does not mention a box, only the canoe; and he adds that sometimes ("as may be") burial in the ground occurred 3 or 4 years after death. The implication is that this had happened to Comcomly and that digging had been the "ressurrectionary labour" required to obtain the skull. In any case the identity and location of the remains undoubtedly would have been well known in a community as small as Astoria was in 1835.

Transference of the skull from moribund Gairdner in Oahu to the Haslar Museum in England via Richardson in 1835-38 is attested by the documents cited. The essential information was inscribed on the skull itself (pl. 2) probably at the time of its receipt at the museum, judging from a comparison of the inscription and the original museum record. Also, according to Harvey (1939, p. 166), "a copy [of Gairdner's letter of transmittal] was discovered by Sir Mervyn Bunbury during the summer of 1938, screwed up and tucked away inside the skull, where it had been hidden for a hundred years."

If all this were not enough to ensure the identity of the skull and to prove that no substitution had occurred during the many years that have elapsed since its exhumation, the unusual form of the skull also provides some supporting evidence. It will be recalled that Gairdner asked the following question of Richardson: "When the phrenologists look at [Comcomly's] frontal development what will they say to this?" As plates 3 and 4 show, the skull vault exhibits extreme artificial deformity—"the Chinook sign of freedom." Although, with the exception of Gairdner's question, eyewitness statements that Comcomly had a flattened head are lacking, most of the early narratives point out that the Chinook practiced intentional head deformation. The epigraph from Washington Irving's book is an example. Obviously, the shape of Comcomly's skull confirms this account of Chinook custom and thereby makes the possibility of later substitution quite unlikely.

To return to Gairdner's question, the skull probably never was examined by a phrenologist. But an indirect and incomplete answer to his question exists in the literature on phrenology. By coincidence, John K. Townsend, the Philadelphia ornithologist,⁶ visited Fort George (Astoria) in September 1836, just about a year after Gairdner's departure for the Hawaiian Islands. While there he obtained, among

⁵ Ray (1938, p. 75) interprets Wilkes's illustration of Comcomly's "tomb" (pl. 1) as an "elevated box interment," basing this opinion, not on a contemporary record, but on the form of the structure and on an earlier report that boxes were sometimes used in place of canoes (Vancouver, 1798, p. 54). (See also footnote 7.)

⁶ Townsend later worked for the National Institute, the forerunner of the U.S. National Museum, and some of the birds that he collected at the mouth of the Columbia River are preserved in the latter museum.

others, the deformed skull of a Chinook "chief,"⁷ which he sent to his friend and fellow townsman Samuel G. Morton, the father of American physical anthropology. In planning his monumental "Crania Americana" (1839), in which this Chinook skull appears as plate 43, Morton took into account the methods of the then new science of phrenology, giving a series of measurements taken according to that system. However, Morton did not feel qualified to evaluate the measurements, and George Combe, whose essay on phrenology is included in the book, states only generalities without reference to particular crania. It is noteworthy, on the other hand, that Morton segregated the phrenological measurements of the "Flatheads of Columbia river," seemingly implying thereby some doubt as to whether phrenological principles applied in such cases. Be this as it may, it is amusing, now that phrenology is discredited, to see how the deformed skull of Townsend's Chinook "chief" rated in comparison with the normally shaped skull of a Swiss (pp. 268, 277):

	Chinook		Swiss		Chinook		Swiss
Amativeness	2.1	2.7		Ideality	4.1	4.5	
Philoprogenitiveness	3.2	3.6		Benevolence	4.1	5.0	
Adhesiveness	3.95	4.4		Causality	3.95	4.8	
Self-esteem	4.6	4.8		Individuality	3.85	4.4	
Approbativeness	4.65	4.7		Order	3.75	4.2	
Firmness	4.7	5.5		Secretiveness	3.2	3.45	
Conscientiousness	4.6	4.9		Cautiousness	4.4	4.55	
Veneration	4.4	5.0		Destructiveness	2.7	2.85	
Hope	4.3	4.8		Combativeness	3.6	3.45	
Marvelousness	4.05	4.9					

Is it because of the deformity that the Chinook rates below the Swiss in every item of this list, except the last—combativeness?

After this diversion, it is desirable to return once more to John Townsend and Samuel Morton. Because of the friendship between

⁷ Townsend's accompanying memorandum (Morton, 1839, pp. 208-209) reads as follows: "The skull of the Chinook is that of a high chief, as was manifest in the superior style in which his canoe was decked out, the unusual fineness of the wrappings with which the body was covered, and the evident care and attention which had been bestowed on the whole arrangement."

Townsend (1839, pp. 255-256) records the visit to the cemetery as follows:

"30th [September].—I visited to-day some cemeteries in the neighborhood of the fort, and obtained the skulls of four Indians. Some of the bodies were simply deposited in on stakes driven into the earth. In these instances it was not difficult to procure the canoes, raised five or six feet from the ground, either in the forks of trees, or supported skulls without disarranging the fabric; but more frequently, they were nailed in boxes, or covered by a small canoe, which was turned bottom upwards, and placed in a larger one, and the whole covered by strips of bark, carefully arranged over them. It was then necessary to use the utmost caution in removing the covering, and also to be careful to leave every thing in the same state in which it was found. . . .

"The corpses of the several different tribes which are buried here, are known by difference in the structure of their canoes; and the *sarcophagi* of the chiefs from those of the common people, by the greater care which has been manifested in the arrangement of the tomb."

Considering that Townsend was acquainted with Gairdner (cf. pp. 229, 233), it is surprising that he makes no mention here of the latter's visit to Comcomly's grave. For that matter it is more surprising that he does not mention Comcomly.

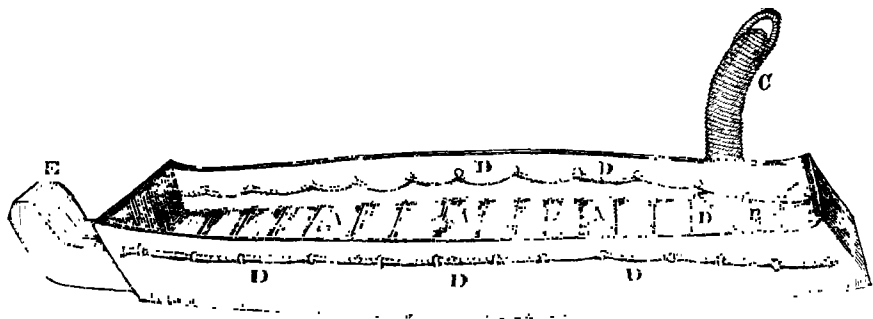


FIGURE 1.—Chinook cradle collected by John K. Townsend during his visit to the mouth of the Columbia River in 1835-36. It was "formed by excavating a single piece of wood about three feet long. Midway between the top and bottom, inside, are little slats of light wood, A,A,A, in a transverse direction, on which are placed a grass mat or bed. The head of the cradle, B, is an excavated chamber, bounded towards the foot by an inclined plane, D, the rounded margin of which supports the child's neck, while the head itself is received into the concavity at B. Attached to the side of the cradle is the pad, C, made of grass, with a loop at the end; this is drawn down over the child's forehead, keeps it in place, and causes the flatness of that part so universal in these people. The lateral loops, D,D,D, are for the purpose of keeping the child's body in a fixed position. The projecting end, E, is rounded, and answers for rocking the cradle, when poised on it, by a rotary motion applied at the opposite end. The head and neck rest on a grass mat or pillow" (Morton, 1839, p. 204).

these two men we have not only the earliest anthropometric description of a Chinook skull, but also probably the earliest illustration (fig. 1) of the type of cradle which Washington Irving mentions (see epigraph) as being responsible for the Chinook cranial deformity.⁸ This particular cradle, which seems to have been overlooked in the literature on the Chinook (cf. Ray, 1938, pp. 69-70; Underhill, 1945, pp. 128-130), is pertinent here mainly because the skull described by Morton, like Comcomly's, is deformed. This is consistent with the claims of Townsend for his specimen. Incidentally, the Townsend cradle is one of two types of deforming apparatus employed by the Chinook. The other type, sketched by Lewis and Clark (see Ray, 1938, fig. 3) and later painted by Catlin (Donaldson, 1886, pl. 42), employed a hinged flattening board to compress the head in much the same manner as a nutcracker is used.

Morton made no special effort to describe the deformities exhibited by the specimens he was reporting, being content apparently to let the illustrations speak for themselves.⁹ In the case of Townsend's

⁸ Although the skull is still preserved in the Academy of Natural Sciences of Philadelphia, its presence there having been noted in 1857 by Meigs, the cradle is not in that institution and its present location had not been discovered at the time of this writing.

⁹ Morton made his drawings by means of a cranograph devised by his friend John S. Phillips (for illustration, see Morton, 1839, p. 294). It consisted of a board 6 feet long and 1 foot wide with a short upright piece attached at each end. The skull, which was posed against one of these uprights, was viewed through a small hole in the other upright. Between the skull and eyepiece, but only 15 inches from the latter, was a square frame holding a piece of glass. The outline of the skull was traced on this glass, yielding a reduction to one quarter. From the glass the outline was transferred to paper and perfected. Later an artist redrew the picture on lithographic stone.

"chief" (pl. 5), he succeeded in getting a fairly accurate lateral profile, but was less successful in the placement of the features within this outline. No other aspects of the skull were illustrated, so these are given here for the first time in the form of photographs (pl. 6). Imperfect though it is, Morton's single illustration constitutes the first description of Chinook deformity based on a skull known to have come from an early 19th-century elevated canoe interment. This fact has been generally overlooked or ignored, because credit is given to Boas (1891), rather than to Morton, for defining the Chinook type of deformity (cf. Oetteking, 1930, pp. 16-17; Dingwall, 1931, p. 163 ff.). By the time Boas came along, of course, it was possible to draw broad conclusions on this subject. However, Boas defined the Chinook deformity type simply from skulls attributed to this tribe. The recovery of deformed skulls from the area traditionally occupied by a tribe undoubtedly provides strong evidence regarding the type of deformity practiced there, but the evidence provided by a historically documented skull, and especially one collected before acculturation has made much headway, establishes the fact much more convincingly. With this in mind, and if for no other reason than to supplement and substantiate Morton's classic report, a description of Comcomly's skull now is in order.

CRANIOMETRY

Having said so much about deformity, it is desirable to take up first the analysis of this trait. For this purpose I will use a combination of the Klaatsch (1909) and Oetteking (1930) schemes of lines and angles. Figure 2 shows a stereographic drawing of Comcomly's skull treated in this fashion and, for comparison, a similar rendition of the skull of Townsend's "chief" (hereafter referred to as No. 462). Most students follow the Klaatsch scheme alone in describing cranial deformities, but so far as the Northwest coast is concerned, Oetteking's (1930) elaboration of this scheme cannot be ignored, especially since it gives a basis for judging variability.

In spite of the existence of such schemes, there is still no general agreement on the lines and angles best suited for characterizing deformity. This being the case, and not wishing to overly complicate the drawings, I will report also a few details not illustrated. For example, the frontal bone being essentially the area between the landmark glabella (G) and bregma (Br), the amount of frontal flattening may be represented by the ratio of the frontal chord length (G-Br) and the maximum distance between this chord and the frontal profile (measured vertical to the chord). The same is true of the parietal (Br-L) and occipital (L-B) areas.

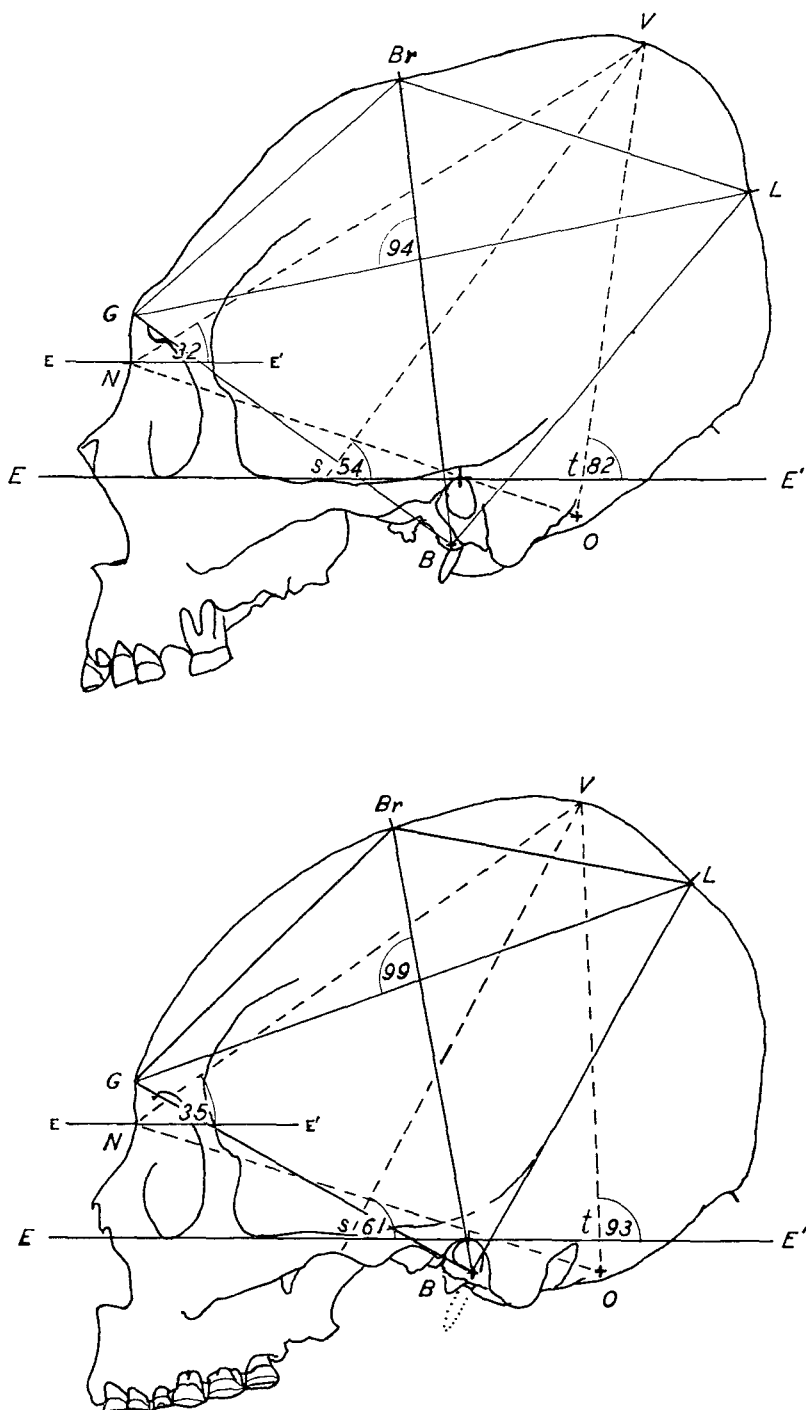


FIGURE 2—Stereographic drawings of the skulls of Comcomly (upper) and of Townsend's Chinook "chief," No. 462 in the Morton Collection, Academy of Natural Sciences, Philadelphia (lower). The added lines are based on Klaatsh and Oetteking craniotrigonometric schemes.

With this explanation it should be clear that table 1 combines angles and ratios derived from figure 2 with whatever comparative data is supplied by Oetteking. Since the latter has confirmed Boas's finding that within the Northwest coast complex of deformity types "Chinook" differs markedly from "Cowichan" and "Koskimo," this table shows (1) that the Chinook tribe really practiced the general type of deformity thus designated, and (2) that the Chinook cradles did not mould the head uniformly. Of course, infants' heads differ to begin with, and handmade cradles vary in their proportions and details, so it should come as no surprise that head flattening within a tribe varies in intensity.

TABLE 1.—Angles and ratios derived from the Klaatsch-Oetteking craniotrigonometric scheme (fig. 2)

Angle or ratio	Comcomly	No. 462	No. 4473*	"Chinook" range†	
				Male	Female
	Degrees	Degrees	Degrees	Degrees	Degrees
Central angle of Klaatsch	94	99	*101	93-105	93-107
Angle VNe'	32	35	*30		
Angle VtE'	82	93	*78		
Angle VsE'	54	61	*50		
Angle of GL to EE'	11	19	†11	7-18	8-19
Angle of BBr to EE'	83	79	†90	78-92	79-93
Angle of NB to EE'	28	23	†28	23-35	25-35
Angle of BO to EE'	13	1	†-2	+14-15	+7-10
Angle of NBr to EE'	46	49	†44	40-55	38-53
Angle of LBr to EE'	17	10	†20	13-33	10-29
Angle of OL to EE'	118	103	†120	105-130	102-123
Frontal height ratio	10.8	11.7	*10.3		
Parietal height ratio	29.9	20.0	*32.1		
Occipital height ratio	28.1	43.6	*24.3		

*Oetteking, 1930, fig. 1, p. 19 of text; an adult (?) female.

†Oetteking, 1930, p. 78 of table of measurements; 58 males, 26 females (not all measurable).

‡Oetteking, 1930, p. 76 of table of measurements.

Table 2 adds many of the standard measurements and indices for Comcomly and No. 462 and includes, for comparison, Oetteking's "Chinook" ranges. Both skulls fall within his male range, but No. 462 tends to be in the lower part of this range. Indeed, were it not for the documentation and the evidence that Oetteking regarded many of his small skulls as males, I would be disposed to doubt the sex identification of No. 462. I have no such doubts regarding the sex of Comcomly's skull.

Does Comcomly's skull tell anything about his age? Plates 3 and 4 show that the joints between the bones of the vault (sutures) are still visible, but are bridged over in many places. Significantly, the

masto-occipital sutures, usually about the last to close, are no longer visible. This could mean that Comcomly was as old as estimated: 65.

Age is reflected also in the teeth. Indians lived on a coarse diet which tended to wear down their teeth rapidly. Comcomly's upper teeth are well worn, so that all those present have a large exposure of dentin. The second molars were lost antemortem, either from caries or from destruction of the supporting bone (pyorrhea). In general, all this suggests an age somewhat below 65. The possibility exists, therefore, that Scouler was misled in estimating Comcomly's age by the general Indian tendency to age rapidly.

In this connection it is interesting to note that No. 462 has open masto-occipital sutures and no tooth loss, but more wear of the front teeth. This "chief" could have been around 40 to 50 years of age.

TABLE 2.—Standard measurements of Comcomly's skull with comparative data

Measurement or index	Comcomly	No. 462	"Chinook" range*	
			Male	Female
Cranial capacity	1,340 cc.	1,175 cc.	1,150-1,630	1,020-1,390
Maximum length of vault	170 mm.	168 mm.	155-182	148-166
Maximum breadth of vault	161 mm.	150 mm.	143-170	138-161
Cranial index	94.7	89.3	81.6-108.4	83.1-102.3
Basion-bregma height	121 mm.	117 mm.	115-145	102-134
Mean height index	73.1	73.6	70.9-89.8	63.8-85.3
Minimum frontal diameter	100 mm.	99 mm.	89-109	86-102
Basion-nasion	97 mm.	97 mm.	87-107	80-103
Basion-prealveolar point	102 mm.	107 mm.		
Nasion-alveolar point	79 mm.	74 mm.	68-83	62-78
Facial angle	63°	61.5°		
Diameter bizygomatic maximum	150 mm.	136 mm.	133-151	123-140
Upper facial index	52.7	54.4	46.8-57.6	47.7-56.8
Nasal height	53 mm.	50.5 mm.	48-60	44-57
Nasal breadth	24 mm.	28 mm.	20-29	20-26
Nasal index	45.3	55.4	36.2-68.0	38.5-56.8
Orbital breadth, right	40 mm.	41 mm.	37-45	35-43
Orbital breadth, left	39 mm.	41 mm.		
Orbital height, right	36 mm.	38 mm.	33-40	32-40
Orbital height, left	35.5 mm.	38 mm.		
Orbital index, mean	90.5	92.7	82.2-102.6	82.0-102.9
Posterior interorbital width	29 mm.	25 mm.	19-29	18-26
External alveolar length	56 mm.	54 mm.	49-60	46-58
External alveolar breadth	68 mm.	66 mm.	61-73	58-68
External alveolar index	121.4	122.2	105.2-138.5	110.9-141.7
Foramen magnum length	33 mm.	33 mm.	28-41	30-36
Foramen magnum breadth	30 mm.	27 mm.	27-35	26-32
Foramen magnum index	90.9	81.8	73.7-100.0	83.9-100.0

*Oettinger, 1930, pp. 32-35, 78-79 of the tables of measurements; 58 males, 26 females (not all measurable).

EPILOGUE

Now that the contribution of Comcomly's skull to anthropology has been established, it is necessary to return to the historical narratives

for a fitting conclusion of this account. It will be recalled that Comcomly met Lewis and Clark and their party, the first of the stream of white men to descend the Columbia River. Before and after this he saw many ships approach or enter the mouth of the river. How he must have wondered about the world beyond the mountains on one side and the sea on the other! He was not destined, of course, to travel so far in life; only his skull traveled. But then, maybe he transmitted some of his longings for travel, or at least for information about foreign lands, to his descendants. One can almost imagine this to be so, because the remarkable adventure of his grandson that will now be outlined is well documented (Lewis and Murakami, 1923).

In 1823 the youngest daughter of Comcomly, then still in her teens, married Archibald McDonald¹⁰ of the Hudson's Bay Company and soon had a son whom they named Ranald McDonald. The father apparently saw to it that Ranald did not receive the traditional Chinook "sign of freedom." But this does not mean that the boy was not free, at least to travel. In 1834 he was sent to school in the Red River Settlement in what is now Manitoba, Canada; and in 1839 he was sent to St. Thomas in southeastern Ontario to work in a bank. Bank work did not suit Ranald, but apparently it did foster thoughts of further travel: this time to Japan, of all places. Japan, it will be recalled, was closed to outsiders in the early 19th century.

During his childhood Ranald had seen Japanese sailors who had been shipwrecked along the Pacific coast near the mouth of the Columbia. Memories of this recurred to him now when he heard about the Japanese Decrees of Exclusion. Together they proved so tantalizing to a boy of 21 that Ranald gave up his job in the bank and started off for the Orient. From Canada he worked his way down the Mississippi to New Orleans and from there somehow reached New York. Late in 1845 he "shipped before the mast" on the *Plymouth* bound for the Sandwich Islands. Finding that the ship was going on from there to Hong Kong, Ranald talked the captain into agreeing to put him adrift in a small boat off the coast of Japan.

Thus it came about in June 1848 that Comcomly's grandson found himself on an island off the northwest coast of Hokkaido (or Yezo). The inhabitants of this part of Japan were Ainu and they treated Ranald very kindly. Nevertheless, Japanese law required that his presence be reported. This led to a series of interrogations in various places ending 10 months later in Nagasaki. During this time, in spite of being confined in somewhat cramped quarters, Ranald conducted a class in English for 14 government interpreters. In the process he himself learned a sort of pidgin Japanese. On April 26, 1849,

¹⁰ The family preferred to spell their surname McDonald rather than MacDonald.

he was delivered to the American authorities. He returned home by way of Australia.

An interesting sidelight on Ranald's adventure is the fact that one of the students in his English class was Moriyama Einosude, who served as the principal interpreter for the Japanese Commissioners during Commodore Perry's negotiations on his second visit to Japan.

In this indirect fashion we get a suggestion of the qualities that made Comcomly a great chief. The present-day Chinook, like Ranald McDonald, do not have, nor do they need, the "sign of freedom." They have no reason, however, to be ashamed that Comcomly bore this "sign."

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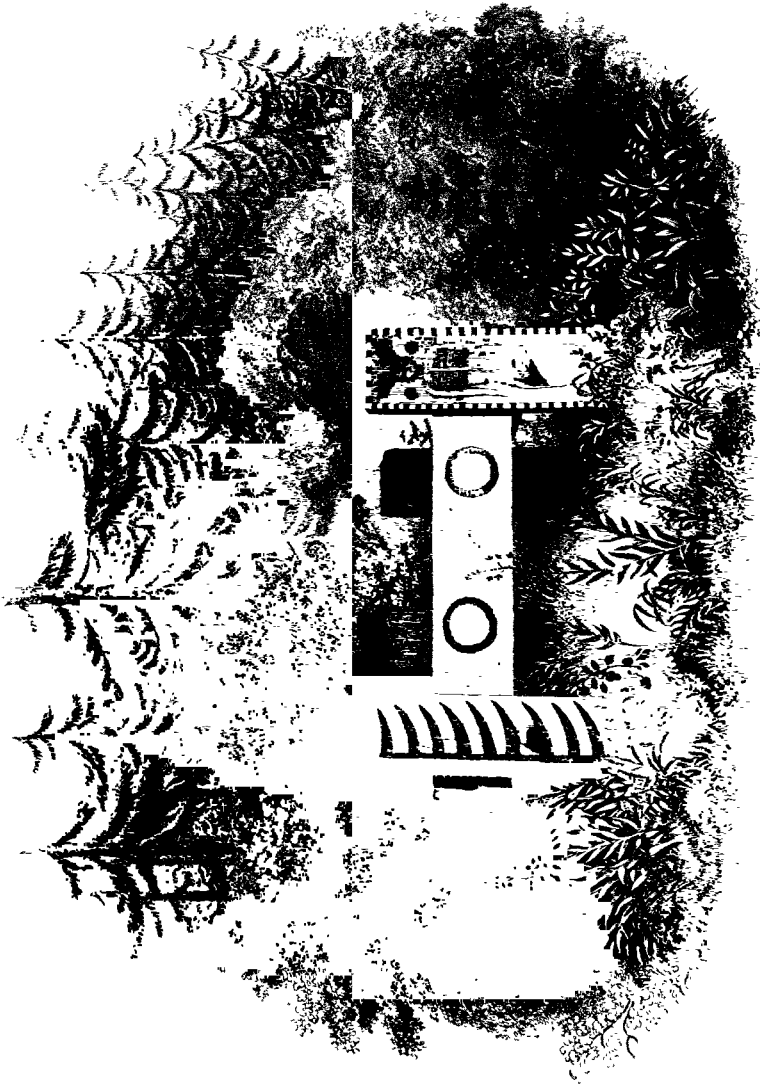
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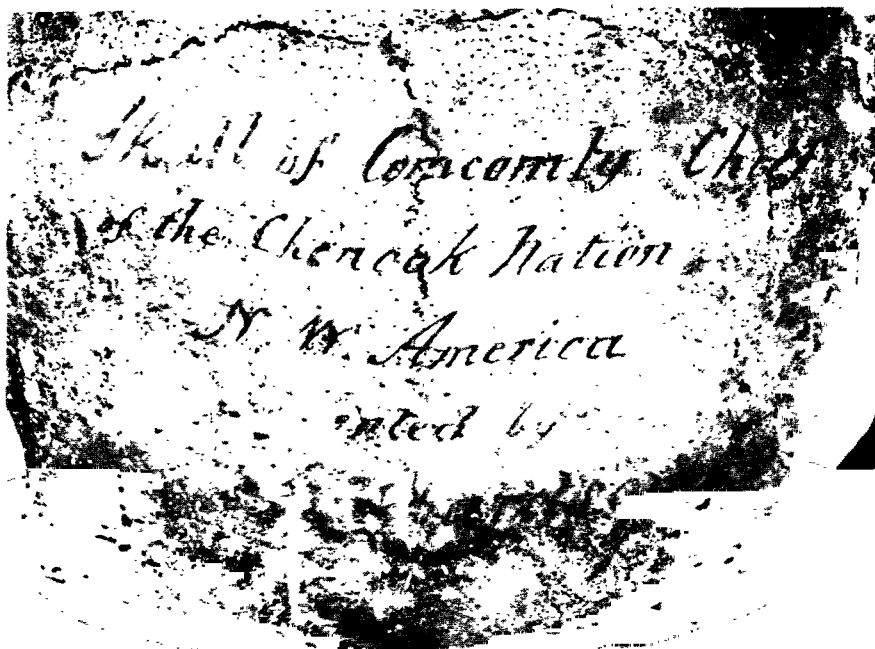
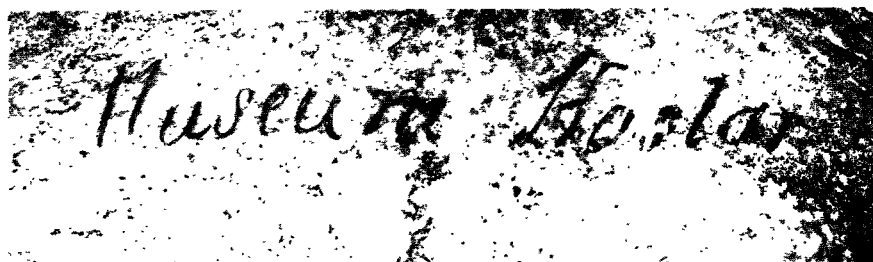
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PLATES



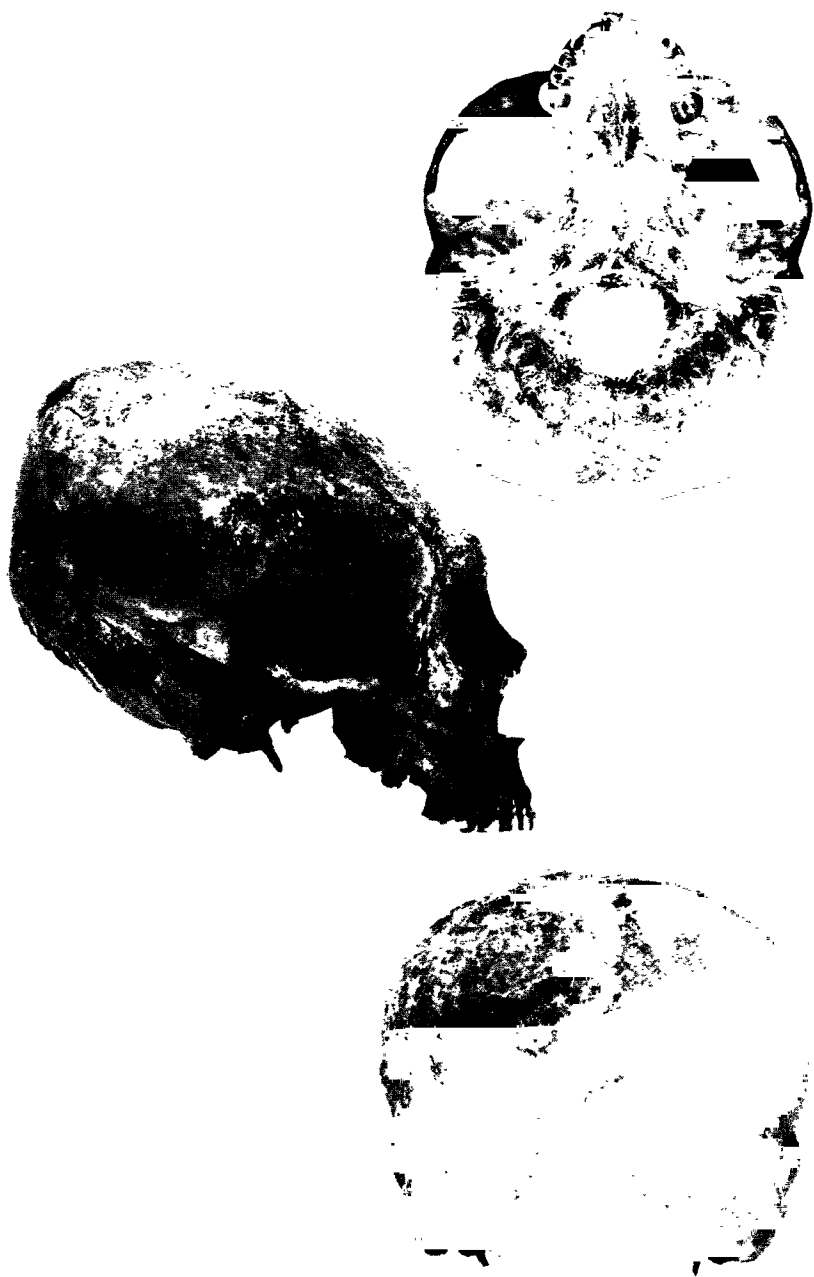
“Concomely’s tomb, Astoria,” sketched by A. T. Agate in 1841 and engraved by W. E. Tucker for Charles Wilkes’s *Narrative of the United States Exploring Expedition*, vol. 4, p. 343.



Inscription, slightly retouched, on Comcomly's skull, probably dating from 1838 when the skull was deposited in the Haslar Museum, England, by Dr John Richardson. The following can be clearly deciphered: Museum Haslar; Skull of Comcomly Chief of the Chinook Nation/N.W. America/[Presented by]—[Richardson].



Front, left side, and top views of Comcomly's skull oriented in the Frankfort position.



Bottom, right side, and back views of Comcomly's skull oriented in the Frankfort position.



Upper right: Lithographic drawing of Townsend's Chinook "chief" reversed and reoriented in the Frankfort position (Morton, 1839, pl. 43). *Middle left:* Photograph of same skull (without lower jaw). The zygomatic arch is deformed by an old fracture. The styloid process has been broken off. *Bottom:* Superimposed outlines of photograph (dotted line) and drawing (solid line) with glabella and the Frankfort horizontal coinciding.



Front, left side, and top views of the skull collected by John K. Townsend in 1836 (No. 462 of the Morton Collection, Academy of Natural Sciences, Philadelphia). (See pl. 5 for view of right side.) Orientation in Frankfort position.

The Muldbjerg Dwelling Place: An Early Neolithic Archeological Site in the Aamosen Bog, West-Zealand, Denmark¹

By J. TROELS-SMITH

The National Museum, Denmark

[With 6 plates]

FOR MANY YEARS peat litter had been harrowed for briquettes in the large Aamosen bog in West-Zealand (figs. 1 and 2), when one day the teeth of the harrow raked up some potsherds and a number of flint flakes. These objects, which were lying on the vast brown surface, gave evidence of a Neolithic dwelling place.

In the period that followed, and during the excavation which went on through several years, it was found that this dwelling place was one of unusual importance. Here the oldest traces of grain and weeds, as well as the oldest bones of domestic cattle and sheep in Denmark, were found.

The following will describe the investigations step by step in order to show how the individual parts of the puzzle—if understood and interpreted correctly—unite into a picture of the dwelling place and the landscape, the people and the animals, and the whole life of a dwelling place as far as a reconstruction has been possible.

The investigations were carried out by the Department of Natural Sciences, the National Museum, Copenhagen.

INVESTIGATIONS IN THE FIELD

EXCAVATION OF THE DWELLING PLACE

Initially two trial trenches were dug across the site in the form of a cross. In this way the first information on extent and stratigraphy was obtained. As the preliminary results had been promising, further investigations were planned. The fieldwork was begun in 1951.

¹ A condensed translation of original article in Danish, which appeared in *Naturens Verden*, July 1957, and is here reprinted by permission of the publishers.

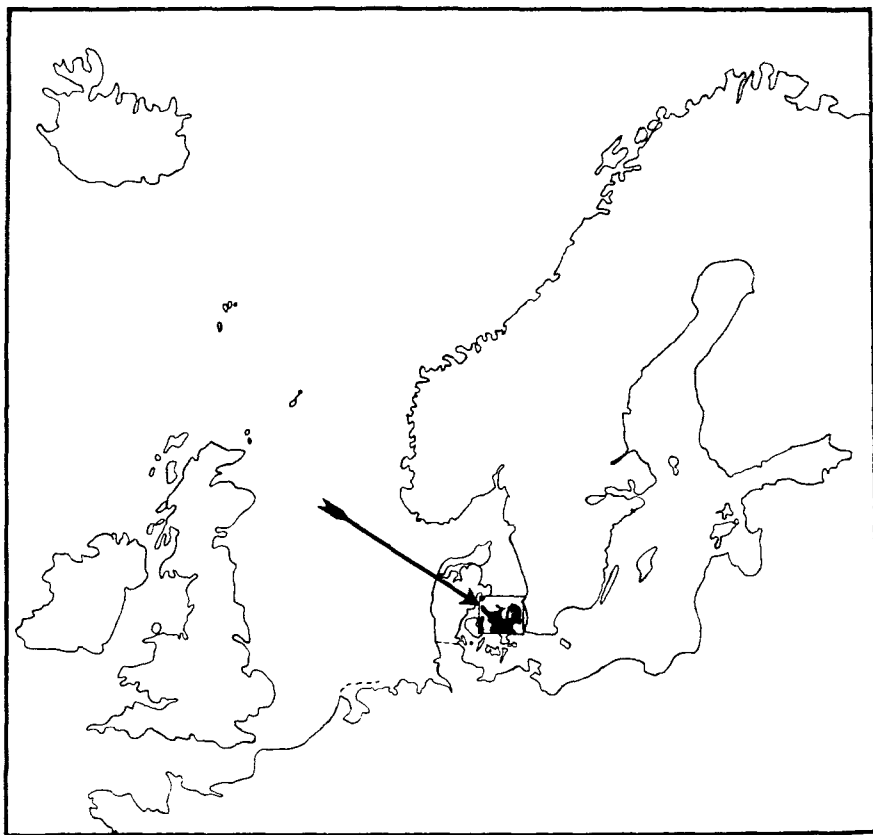


FIGURE 1.—The location of the Aamosen bog, West-Zealand, Denmark. The area marked with a square is shown enlarged in figure 2.

One of the greatest difficulties connected with excavations in bogs is the high water level. Therefore, the most practical thing to do is to drain the area under investigation by digging a system of trenches all around it. In case it is a larger settlement, it may be divided into a number of blocks which can be examined one after another (pl. 1).

The purpose of an excavation is not only to bring to light the various artifacts, flint tools, potsherds, etc., but also to find out how they lie in relation to each other and to make all other possible observations. Planning and carrying out such an excavation are difficult for two reasons: (1) During the excavation and investigation the site itself is destroyed, and observations not made in the course of the excavation work will be irrevocably lost. (2) Every excavator works with a certain fund of knowledge and a certain expectation of what he may find and observe, with the result that some of the things sought are found, while others which are also sought are not. In conducting an excavation, it is essential to let imagination work upon the

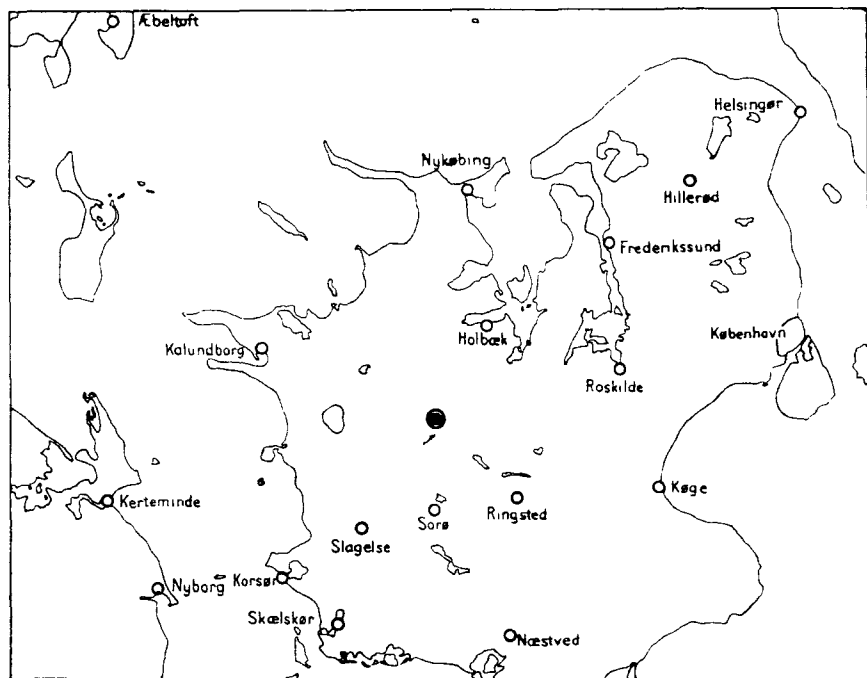


FIGURE 2.—The Muldbjerg dwelling place, situated in the 8,000-acre Aamosen bog. The solid circle indicates the location of the dwelling place.

observations in an effort to see things which have not yet been demonstrated, and in particular to record objectively and faithfully everything found or observed independent of whether, at the time of the excavation, it fits into present theories. This means that the work must be performed in such a way that it will be possible later on to prepare detailed maps and sections showing not only the exact position of the objects found but also the different layers and all other observations made during the excavation.

During the excavation a record is kept in which every object found is numbered consecutively. (So far 33,231 numbered items have been excavated at Muldbjerg.) Each item is classified: Nut shell, flint chip, awl, piece of bark, etc., and the coordinates and level of each are recorded. All the objects are then provided with a tag carrying the number of the object, and are wrapped in paper. The finds are gathered daily in small bags (pl. 2, fig. 1).

INVESTIGATION OF THE DEPOSITS

Dwelling places situated on the solid ground leave only a thin layer of rubbish consisting of flint chips, broken tools, potsherds, and some charcoal. Bones are usually much disintegrated or have totally disappeared along with other organic material. Such a dwelling place

may have been inhabited continuously for a long period, or the habitation may have been interrupted for certain periods perhaps covering several thousand years. In excavating such habitation sites there is no possibility of deciding whether objects found together really are contemporaneous. In lakes and bogs this is different. Here, continuous growth takes place in the shore zones, and every spring a new, luxuriant vegetation of swamp plants grows up covering the remains left the previous year. At the bottom of the lake one paper-thin layer of dead micro-organisms and pulverized plant fragments is deposited upon the preceding, and little by little, as the years pass, the lake will be filled up and become a bog. If we imagine a dwelling place situated at the shore of such a lake or perhaps somewhere in the filled-up bog, the rubbish and the implements left will be placed at the proper position within this sequence of layers. Moreover, the bog will preserve not only the imperishable flint and the rather resistant potsherds but also wood and bark, bones, grain, and weed seeds.

The layers of the bog will not only preserve the remains of the settlement, but at the same time the peat and lake deposits will yield information on the former plant and animal life by their content of seeds, bark and twigs, pollen grains, bones, shells, and other organic remains. They also provide us with means for dating the layers. For such reasons it is of the utmost importance that these deposits are thoroughly investigated and above all that the stratigraphy of the layers in relation to the habitation remains is established.

Just as it is important to be able to reconstruct the position of the different culture remains in plane and section, it is equally important to be able to reconstruct the position of the different deposits which surround the culture remains. This is done by measuring the layers in the long peat walls which appear during the excavation. The excavation is done in sections of half a meter in width from the edge of the peat block formed by the trial trenches (drainage trenches).

When the wall is dug out, it is cut smoothly plane and vertical like a well-laid brick wall. In that way we get a clear picture of the different layers in the section. It is now a question of using the eyes to note the color of the different strata both immediately after the cutting of the wall and later when the air has darkened the layers. The way in which the deposits dry will also give information about the type and structure of the layers. It is important to distinguish the strata of the same color and structure to be able to reproduce this picture. In practice this is done by drawing vertical lines on the wall at a distance of 25 cm. Where these lines cross the horizontal layers the intersections are marked by matches put into the wall. The intersections are then drawn in a notebook so that all the hori-

zontal measures are correct according to the scale of the drawing. Next, all the vertical measures are leveled out. In this way it is possible later to give a correct picture of the peat wall and the layers in it based upon the drawings and the levels (pl. 1).

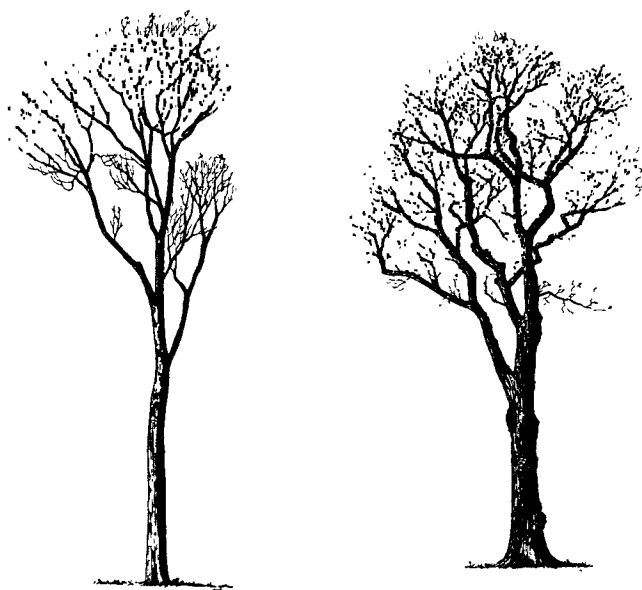


FIGURE 3 (left).—Ash (*Fraxinus excelsior* L.).

FIGURE 4 (right).—Wych elm (*Ulmus glabra* Huds.). (Drawings by A. Noll Sørensen.)

The next task is to characterize the various layers that have been distinguished. Most of the layers consist of a mixture of different components. Fen peat, for instance, often contains the following elements: Roots and rootlets of herbaceous plants (*Turfa herbacea*); fragments of stems and leaves of herbaceous plants (*Detritus herbosus*); minor parts of alder twigs (*Detritus lignosus*); and finally mud or, as it is also called, gyttja (*Limus detrituosus*). Just as a chemical compound may be characterized by a simple formula giving the proportions of the atoms in the molecule, it is also possible to characterize a deposit by the proportions of the components contained in the layer. For the sake of later considerations regarding the genesis of the layer, it is important to know exactly how the deposit is built up and the components of which it consists.

The excavation of artifacts, the determination of deposits, and the characterization of the composition of the various deposits should finally result in drawings both in plane and section showing the layers provided with deposit symbols that indicate the elements of which the layers are composed. Together with the photographs, the draw-

ings in plane and section form the solid basis on which all later work is built.

SAMPLING METHODS

The possibilities of carrying out investigations in the field without the use of instruments and chemicals are limited. Therefore, it is important to take samples for later investigation in the laboratory. These consist of samples for pollen analysis; samples for investigation of seeds, fruits, and shells; and samples for radiocarbon dating.

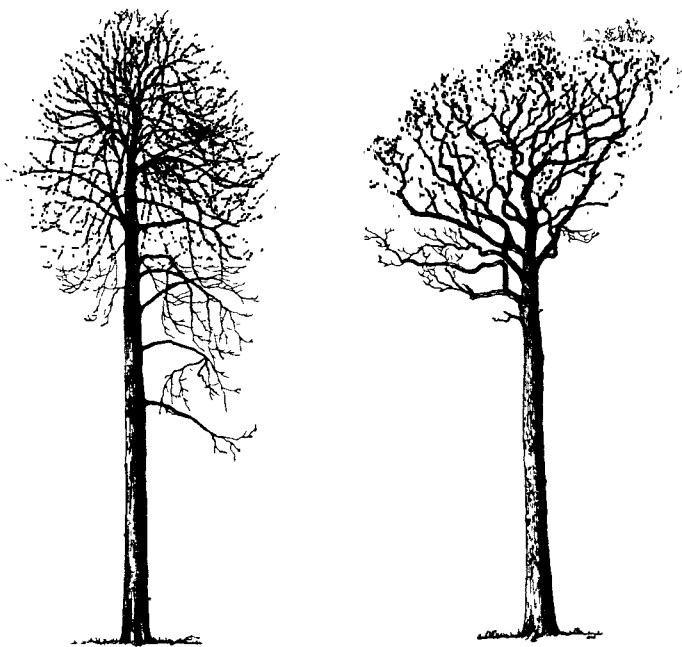


FIGURE 5 (left).—Small-leaved linden (*Tilia cordata* Mill.).

FIGURE 6 (right).—Oak (*Quercus robur* L.). (Drawings by A. Noll Sørensen.)

The pollen samples are taken in small vials which are pressed into the properly cleaned peat wall. The vertical distance between the samples is usually 2.5 cm.; in special cases they are taken at still smaller intervals. The pollen grains being microscopic, it is very important that the samples be pure; i.e., that they are not contaminated with peat from the layers above or below. After the sample has been taken, the vial is carefully corked and later sealed with paraffin so as to avoid contamination.

In order to investigate the content of seeds and fruits, small sticks and twigs, and remains of insects or shells in the peat layers, larger samples are taken, usually about 200 cm. This is done by cutting a peat column out of the section. The column usually is 10 cm. broad and 10 cm. thick, and is cut into slices 2 cm. thick. Each slice is

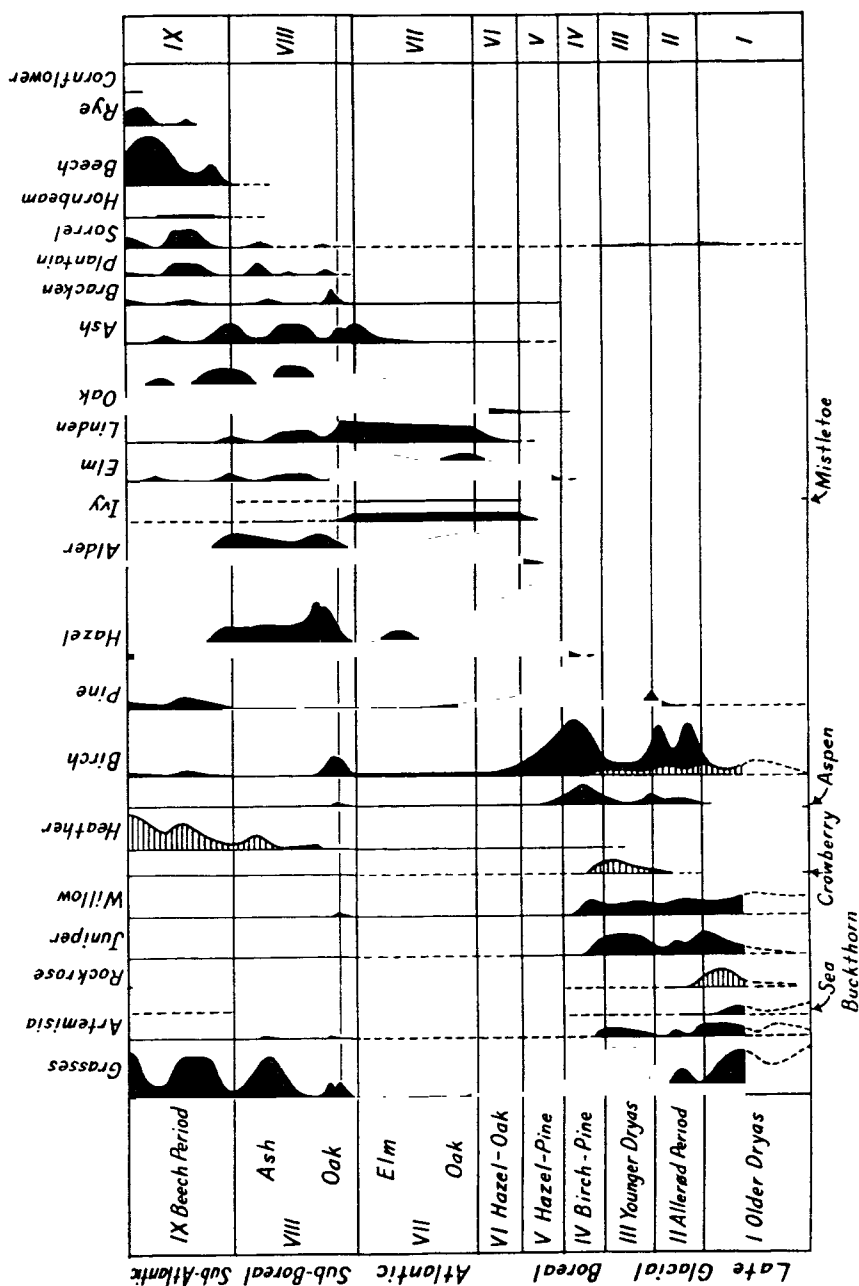


FIGURE 7.—Diagram showing the vegetational development in Denmark. The position of the Muldbjerg dwelling place in the diagram is indicated by the thin line in the lower part of zone VIII. (Prepared by Johs. Iversen, Geological Survey of Denmark.)

put in a plastic bag and sent to the laboratory where it is preserved in alcohol.

In collecting samples for radiocarbon dating, it is obviously undesirable to take out a thick sample which might comprise a period of several hundred years. It is essential, therefore, to take a slice of peat as thin as possible, preferably less than 1 cm. thick. In order to avoid contamination of these samples by mold or mildew they are placed in a drying chamber under controlled heat as soon as possible, after which they may be kept for years in well-closed plastic bags.

LABORATORY WORK

REGISTRATION OF ARTIFACTS AND BONES

The investigation of the Muldbjerg dwelling place has gone on for several years. Usually, the fieldwork was initiated in May-June, and often continued until the end of November or even until the middle of December (when snow and frost forced an end to it). After the return to the laboratory a lot of work had to be done. All the bags filled with culture remains were unpacked, the objects provided with numbers written with india ink, and the finds compared with the excavation records. In the laboratory there is more leisure for studying the artifacts, and often details are observed which have been overlooked during the excavation. In that way the excavation records may be corrected.

Many objects are so friable when found that they have to be strengthened in various ways. This concerns first of all the potsherds. Though a potsherd may appear intact when lying in the peat layer, it often falls apart while drying. In such cases it is necessary to harden each single bit by means of a plastic-lac. When all the fragments have been hardened they must be glued together; thus the original sherd is restored in a durable way. Frequently bone tools and bones are so damaged that they must be strengthened by a preparation with plastic-lac or wax. Wooden objects are the most difficult to preserve, but in recent years the Department of Preservation at the Danish National Museum has achieved good results by special treatments which make it possible to dry the wood in such a way that it does not lose its original shape.

When all the excavated objects have been examined, prepared, and provided with numbers, the worn record books, which are yellow from peat litter and stained from rain, can be retyped. In that way records on all the excavated objects are kept in numerical order. In this manner it is possible, from the number of an object, to find its position and level in the field. However, the information most often desired is what has been found along a surveyed section. Therefore, it is necessary to make another record of all objects found within a given one-quarter square meter. This is done by cutting

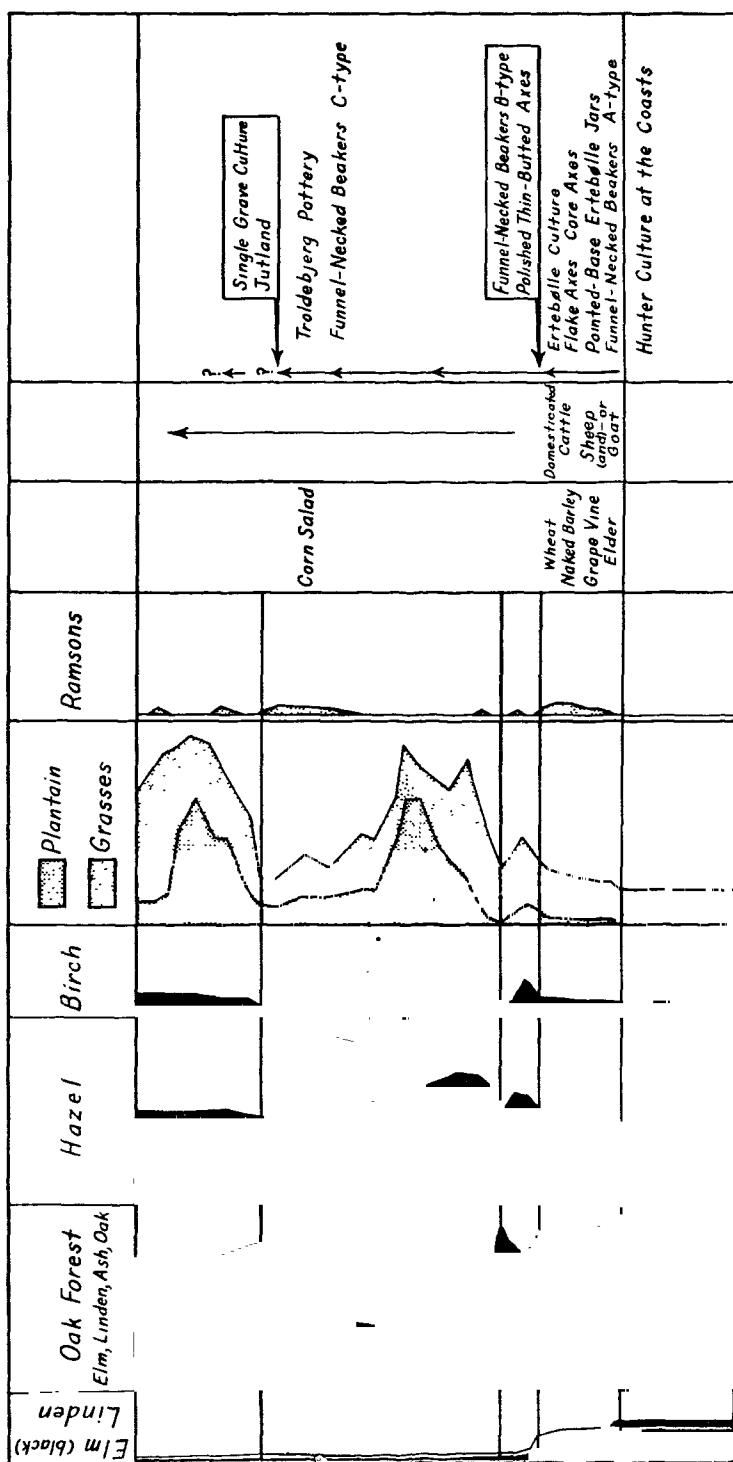


FIGURE 8.—Detailed diagram of the vegetational history during the upper part of pollen zone VII and the lower part of pollen zone VIII. The Muldbjerg dwelling place belongs to the period labeled "Wheat, Naked Barley, Grape Vine, Elder." The drastic changes higher in the diagram were caused by immigrant herdsmen who cleared large parts of the forests for pastures. (Prepared on the basis of pollen analyses by Svend Jørgensen and Troels-Smith from Aamosen and Sørbylille, Zealand, and Dyrholm, Jutland.)

up a copy of the first record and rearranging and pinning together the pieces containing the information (type of object, coordinates, and level, as well as the number) pertaining to all objects found within the same one-quarter square meter in the field. From these slips there is written a record showing for each section the implements found there, and the pieces of flint, the bones, bark, charcoal, nut shells, and other remains—each category separately.

The bone fragments represent a chapter of their own. They are examined at the Zoological Museum, where they are carefully studied to determine the animals from which they originated. At the same time there is an opportunity to make a number of other observations, e.g., as to where the bones had been cut, or how they had been broken in order to extract the marrow. Though the bone finds have been entered in the main numerical and locality records, it is necessary, when identifications have been completed, to make another numerical record and one arranged according to species of animals.

DRAWING OF SECTIONS

The measurements of the peat walls made during the excavations have to be redrawn on grid paper with a pencil to form the basis for later drawings in india ink. Three copies of each section are made: One on which the borderlines of the different deposits are drawn and the layers are numbered corresponding to a list of the geological diagnosis of the bog deposits; one copy with the borderlines of the layers and a projection of all the culture remains (flint chips, potsherds, nut shells, bone fragments, etc.) found within 25 cm. before and behind the section (in this way a general view of the relations between the culture layer or layers and the deposits of the bog is acquired); and a third copy drawn like the first one but with the numbers replaced by symbols that will enable an experienced geologist to read the composition of the deposits directly from this symbol section.

INVESTIGATION OF THE POLLEN SAMPLES

Pollen is the male semen of the flowers, and wind-pollinated plants produce enormous quantities which are carried by the wind to other flowers. By far the largest part of the pollen, however, is biologically wasted. It is sprinkled over the surface of the earth and destroyed, except for that which happens to fall on moist bogs or into lakes, where, incorporated in peat and mud layers, it may be preserved throughout millennia. The pollen grains consist of an outer wall, which is very resistant and which surrounds the plasma. This inner plasma decomposes rapidly and perishes. In a single cubic centimeter of peat or gyttja, several hundred thousands of pollen grains may be found. They are very small, usually about 20 to 50 microns, 1

micron being $1/1,000$ mm. The fact that pollen from the same species is all alike and is more or less different from that of related species makes it possible to determine from which plant a given pollen grain originated.

Although it is possible to establish the presence of pollen grains in a peat sample just by stirring it in water and placing a drop of the liquid under a microscope, it is necessary to apply a careful chemical treatment for two reasons. First, the pollen must be concentrated sufficiently so that only a few slides need be counted. This is done by removing, by various treatments, the extraneous plant remains and the possible clay and lime in the samples; the pollen grains are so resistant that they can stand treatment with both hydrofluoric acid and concentrated sulfuric acid without being destroyed. Next the samples are treated chemically to make the pollen grains swell so that certain details become more marked. Often it is profitable to add some dyestuff which will stain the pollen but not the other components of the peat thus facilitating the counting of the grains.

When the chemical treatment is concluded, microscope slides are prepared. A drop is placed on the slide and a thin cover glass is fixed on the top of it with molten wax. In this way the slide is sealed and can be kept for decades.

The pollen grains are now ready to be counted. From each sample are counted on an average 2,000 to 3,000 pollen grains, which usually requires two days by a skilled pollen analyst. The common pollen grains, i.e., those of the forest trees and a number of herbs, are so characteristic that a determination can be made immediately, but now and then pollen grains are encountered which have not been observed before, and then the difficulties arise. Determination of the species of the pollen requires, of course, a thorough knowledge of the pollen of contemporary plants. The study of modern pollen, therefore, must be carried on together with the study of fossil pollen. This necessitates the preparation of slides of pollen of contemporary plants, and the classification of the pollen according to shape, structure, and surface sculpture. However, it is often necessary to retain the unknown pollen types, so-called X-pollen, not immediately identifiable, with a description, a drawing, or a photograph for final determination at a later time.

By counting the number of pollen grains from the different plant species, knowledge is gained of the various trees and herbs which were growing in the surroundings of the bog when the peat sample was deposited, and the relative abundance of each species.

SEED ANALYSES

The peat samples which are taken for investigation of seeds and fruits also have to undergo a chemical treatment. They are placed

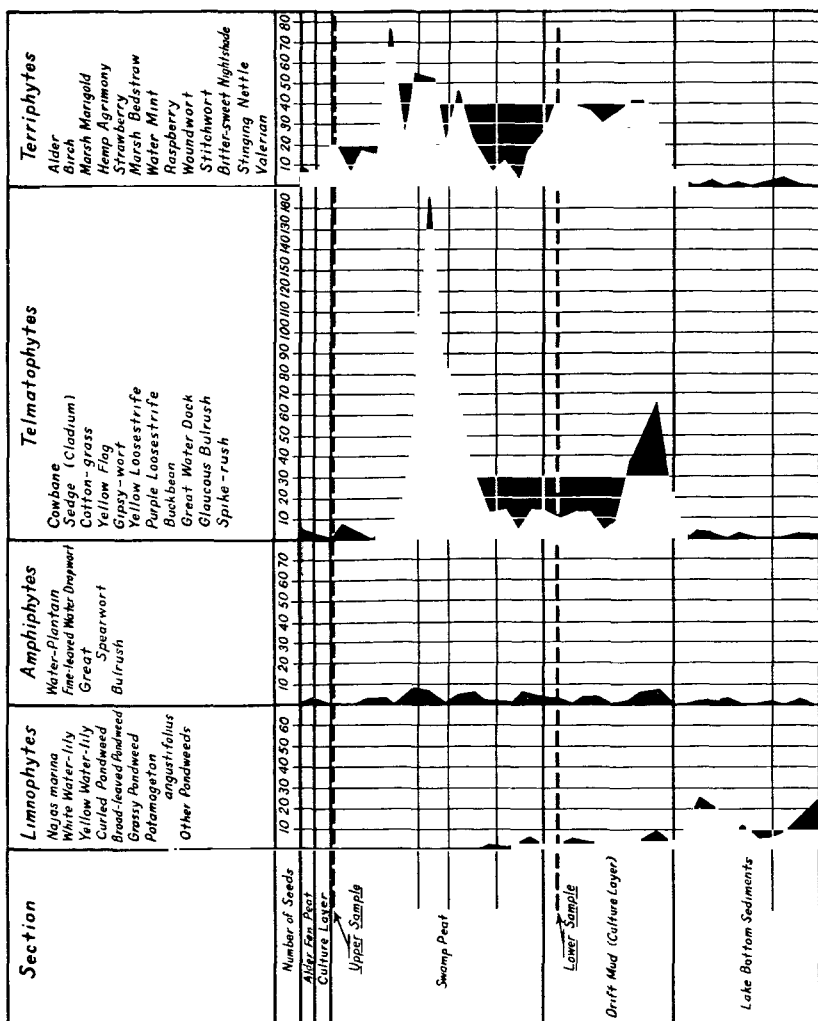


FIGURE 9.—Diagram showing the occurrence of seeds and fruits of different plants in a peat column from the Muldbjerg dwelling place. The upper sample is from the culture layer proper; the lower one is from the drift mud underneath the floating island and is contemporary with the culture layer. (Analysis by Bent Fredskild.)

in dilute nitric acid, in which they are slightly oxidized so that the sample falls apart, and the peat snuff can easily be washed away by pouring the sample into a fine-meshed sieve. By this treatment the seeds and fruits become air-filled and will ascend to the surface when poured into a soup plate, while the larger plant fragments sink to the bottom. With a fine brush the single seeds and fruits are collected on a watch glass and are later sorted according to species and placed in sample vials. By comparison with seeds and fruits of contemporary plants the specimens are identified as to genus and species. Thus from study of each peat sample it is known, layer by layer, which plants were growing on the spot, and in what proportion.

WOOD IDENTIFICATIONS

Charcoal, twigs, and pieces of branches found during the excavation may also tell about the vegetation. Oak and beech are most easily determined, usually with the naked eye or with the aid of a good magnifying glass. But in most cases it is necessary to prepare a thin section of the wood, which is examined under a microscope at about 100-times magnification. In that way the fine structure of the plant tissue becomes visible, making it possible to determine the trees and shrubs from which the charcoal, sticks, and twigs originated.

RESULT OF THE INVESTIGATIONS

THE TWO CULTURE LAYERS—THE FLOATING ISLAND

Through the excavation and the surveyed sections we have obtained a knowledge of the structure of the bog (figs. 9 and 17): At the bottom of the section we find gyttja and mud sediments which were deposited in a lake. Above it is a dark-colored layer 30 to 40 cm. thick consisting of plant remains, leaves, and fragments of branches. Fragments of pots, bones, flint chips, and charcoal occur scattered within this lower culture layer. This layer was also deposited in a lake but in low water near the shore. This is followed by a 40-cm.-thick layer which, at the bottom, is composed of light gyttja interwoven with fine plant roots. Upward the roots dominate and the deposit darkens. At the top of this layer the plant roots are partially transformed into a dark homogeneous peat mass. Thereupon follows a thin culture layer which has a dirty gray color from charcoal dust and broken shells, and here we find a great number of flint chips, small potsherds, and bits of bones (upper culture layer). At the top the series of layers ends with a thick peat layer interwoven with alder roots.

The striking thing about this section is that it comprises two culture layers: a lower one deposited in water, and an upper one resting on peat which was formed in a bog. At first glance one would believe that the lower layer was older and the upper younger, and that they were separated in time by several hundred, perhaps thousand, years.

Nevertheless the artifacts in the two layers are alike; even the types of the vessels are identical. Further, it was proved that a potsherd found in the upper culture layer is part of a sherd found in the lower layer, the two surfaces of the fracture matching exactly. There is no doubt, therefore, that the culture remains in the two layers are contemporaneous, though they are separated by a deposit about 40 cm. thick. Another significant fact is that there are cracks in the peat layer separating the two culture layers, and in some of the sections it can be seen how things from the upper culture layer have fallen through these cracks and have spread in the lower layer. To this we can add another observation throwing light on the problem. The pollen analysis shows that the upper part of the substratum (the former lake bottom) has exactly the same age as the lower part of the peat and gyttja layer that separates the two culture layers. Pollen analysis from the lower culture layer shows, however, that this is considerably younger than the layers surrounding it; i.e., younger than the layer it rests on and also younger than the one directly above.

The only possible explanation is that the upper culture layer originates from a dwelling place on a floating island. The inhabitants of the island threw their rubbish into the lake, and the waves washed a part of these culture remains underneath the floating island, together with leaves and branches, and finally the interspace between the floating island and the former bottom of the lake was filled with washed-in plant and culture remains.

But how is such a floating island created? As mentioned above, the pollen analysis shows that the upper part of the substratum and the lower part of the floating peat island are of the same age, which means that the peat island at some previous time must have lain directly upon the layers which formed the lake bottom; namely, before the peat rose as an island. The reason for the peat breaking away from its base must be a rise of the water level in the lake. It is characteristic of bog plants that their roots are hollow and filled with air. These cavities are in reality a kind of oxidation system that enables the plants to grow in peat poor in oxygen. When such peat formations are covered with one-half to 1 meter of water, the buoyancy will be sufficient to make the peat layers break away from the bottom and rise like a ball which has been held under water (fig. 10). Such floating peat islands are still being formed; e.g., when mill ponds that have been drained for some time are dammed (pl. 2, fig. 2).

THE LOCAL VEGETATION

The plants that grew on the floating island and along its shores have left traces such as seeds and fruits (fig. 9). On the dwelling place itself the vegetation probably was rather poor, and only some grass, perhaps some moss, was able to resist the tramping feet. A few larger

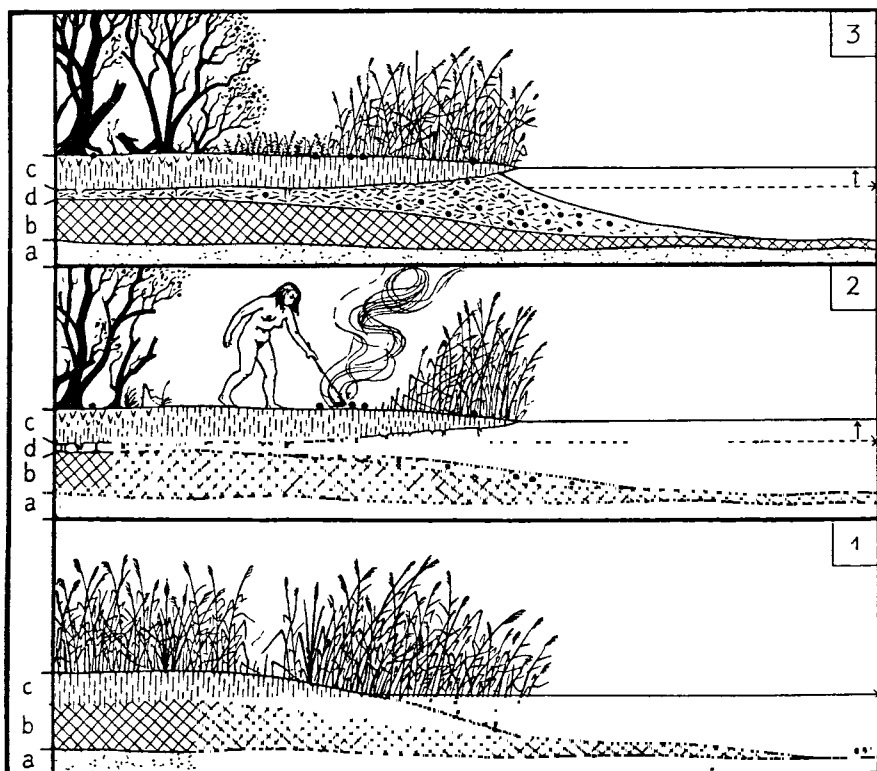


FIGURE 10.—Sketches showing the genesis of a floating island. 1, A lake shore with a vegetation of reeds. 2, The water level rises, and buoyancy of the air-filled roots of the swamp plants makes the swamp peat tear away from the substratum and rise so that it floats on the water. The island becomes inhabited. (The scale is indicated by the size of the woman.) 3, Plant remains are washed underneath the floating island, and gradually the interspace between the island and the bottom is filled up. (Drawing by B. Brorson Christensen.)

alders and willows were spared, and also the stinging nettles, which people avoided. The seeds of strawberries and raspberries found here probably do not indicate that these plants grew on the spot. It seems more likely that the berries were gathered at another place and left at the village site in the form of excrements. The peat island was, on the other hand, encircled by a fertile growth of swamp plants, the seeds and fruits of which can be found washed in underneath the island. Nearest to the shore grew marsh marigold and various sedges, while waterplantain, gipsywort, purple loosestrife, yellow loosestrife, and mint needed more moisture. The odorous valerian lifted its flowers above the other plants, bittersweet nightshade grew tall in the open spots of the swamp, and bindweed clung to rush and reed. Farther out in the water there was a dense growth of reeds and *cladium*, and farthest out were the blue-green clusters of bulrush. And wherever there was a view through the reeds, water covered with yellow water-lilies could be seen.

Also the charcoal remaining from the fires that had been lit can tell about the vegetation of the place. Out of 487 pieces of charcoal, 321 were alder, 65 hazel, 49 oak, 37 willow, 10 elm, and 5 linden (figs. 3-6). It is obvious that most of the wood was gathered on the spot or in the immediate vicinity, where alder seems to have been the most common tree. Less interest was taken in willow, and the bits that were found of hazel, oak, lime, and elm probably are rubbish from timber which had been taken to the place from the solid land at least 3 to 4 km. away.

THE VEGETATION OF THE REGION

Seeds and fruits do not fall far from the mother plant, while pollen grains are spread over a large area (fig. 7). The pollen analyses thus give a picture of the vegetation of the whole surrounding area. The forest dominates, and among the trees it is the oak and its associates—elm, linden, and ash—that prevail. Also the hazel was represented, and here and there grew the dark-green yew tree which was suitable for the production of bows. Other trees, like the yew, were more rare: Crabapple, buckthorn, alder buckthorn, and shrubs such as spindle-tree and guelder-rose. The ivy was creeping up the trunks, and also the mistletoe was growing with its sticky berries which were suitable for bird lime. Apparently the forest was untouched. Man had not begun to influence nature—at least not to any appreciable extent. The country was covered with primeval forest, and rivers and lakes were highways and stopping places for the traffic of that time. But, as we shall see later, certain traces reveal that man had slowly begun his attack on the immense primeval forest.

THE FAUNA OF THE REGION

Although the prevailing primeval forest was not very hospitable toward the animals, the bones found do show that it was worth while being a hunter. Red deer and roe found their way to the water for drinking, and the wild boars rummaged the earth in their search for roots. On quiet evenings it would have been possible to hear the small hedgehogs potter about in the withered leaves hunting worms and insects. The beaver built dams and gnawed the fresh bark, the otter went hunting for fishes, and there is no doubt that the muskrat was living in the shores of the floating island and was a welcome game for the boys on the place.

A large number of birds lived at the lake. Swans, mallards, pin-tails, and shovelers had their nests in the swamps, and in the twilight the teal passed over the peat islet with whirring wings. In the lake there was good fishing for perch, pike, and trench.

IN WHAT PART OF THE YEAR WAS THE PEAT ISLAND INHABITED?

It is somewhat remarkable that these people settled down upon a floating island in a big lake. It might appear reasonable that they

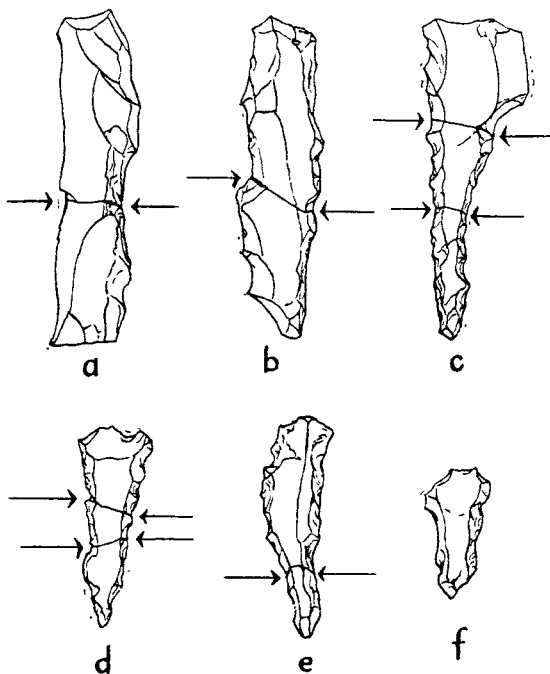


FIGURE 11.—Manufacture of drill points. The arrows indicate location of fracture. *a*, Blade chipped along one side; *b*, blade chipped along both sides; *c*, partly finished drill point; *d*, almost finished drill point; *e*, drill point showing signs of wear, and broken in use; *f*, drill point totally worn down. (Actual size.) (Drawings by A. Noll Sørensen.)

lived there during the summer, but in the winter one would think it an unpleasant place. But is there any possibility of learning what time of the year the island was inhabited? Yes; various things reveal it:

During the excavation of the culture layer about 700 willow and hazel twigs were found, all of them about 1 meter or more long (pl. 4, fig. 1). They were placed together in 3 to 4 bundles, and apparently were collected for the purpose of making fish traps. Such plaited fish traps have been used up to the present time and are known as far back as about 5000 B.C. Cross sections of a great number of the twigs were examined by microscope (pl. 4, fig. 2), and all of them proved to be not quite 2 years old, as the youngest annual rings were not fully developed. Examination of the present growth of annual rings in similar plants during January to October makes it possible to determine at what time of year the twigs from the Muldbjerg dwelling place were cut, and proves that all the twigs must have been cut at the beginning of June.

It has been mentioned earlier that fruit seeds of strawberry and raspberry were found at the dwelling place. In one case large quantities were found lying together and in such a way in the peat that there could be no doubt that they belonged to human excrement. Many of the somewhat larger raspberry seeds had been crushed be-

tween the teeth before being swallowed, in contrast with the smaller strawberry seeds. As the strawberry season precedes the raspberry season, it is only from the beginning to the middle of July that it is possible to enjoy both of these tasty berries. In this period at least the dwelling place must have been occupied.

A large number of crushed nut shells were found spread all over the dwelling place, and, therefore, it is reasonable to assume that the site was inhabited until September.

The bones give the same evidence. Bones from barely fledged birds indicate a habitation in June and July, and finds of bittern and other migratory birds point to the summer half year. Characteristic winter visitors among the migratory birds have not been found.

Hence we are sure that the dwelling place was inhabited in the months of June, July, August, and September, while there is nothing to indicate that it was inhabited during the rest of the year.

DATING IN RELATION TO THE VEGETATIONAL HISTORY

Since the great glaciers retreated from Denmark, one type of vegetation has followed another (fig. 7). Right after the Ice Age the herbs moved in, along with sedges and grasses, and here and there dwarf willow and dwarf birch. The country was naked and bare, and no trees gave shade. Later on, when it became warmer, the birch arrived, and a little later the dark-green pine trees. At the same time the aspen spread, just as did the rowan. When it got still warmer, large hazel shrubs began to spread all over the country, but in due time they were superseded by elm, oak, linden, and ash. These trees did not migrate rapidly, but once they had arrived, they were difficult to remove. Little by little the trees conquered the country, their shade closed off the light from the undergrowth, and it became dark and silent beneath the high tops. At a certain time, however, small changes in the vegetation occurred: hazel began spreading again, the elms receded, and simultaneously the elders (plantain) appeared for the first time. A new epoch was announced (fig. 8). The first farmers had begun to lighten the primeval forest. Development began on a small scale, which was to make Denmark one of the least-forested countries in Europe. Only a long time after man had begun this clearing work did beech appear, but once it had arrived it spread rapidly. Finally, as a challenge to the heath, man began to break up the heather and to plant spruce.

This very development can be reconstructed by means of pollen analysis. At the same time this method makes it possible to date a given sample in relation to the history of the forests. Thus the Muldbjerg dwelling place can be dated to the time when the first farmers had just begun to clear the forests—or, more precisely, to the last part of the oak-forest period.

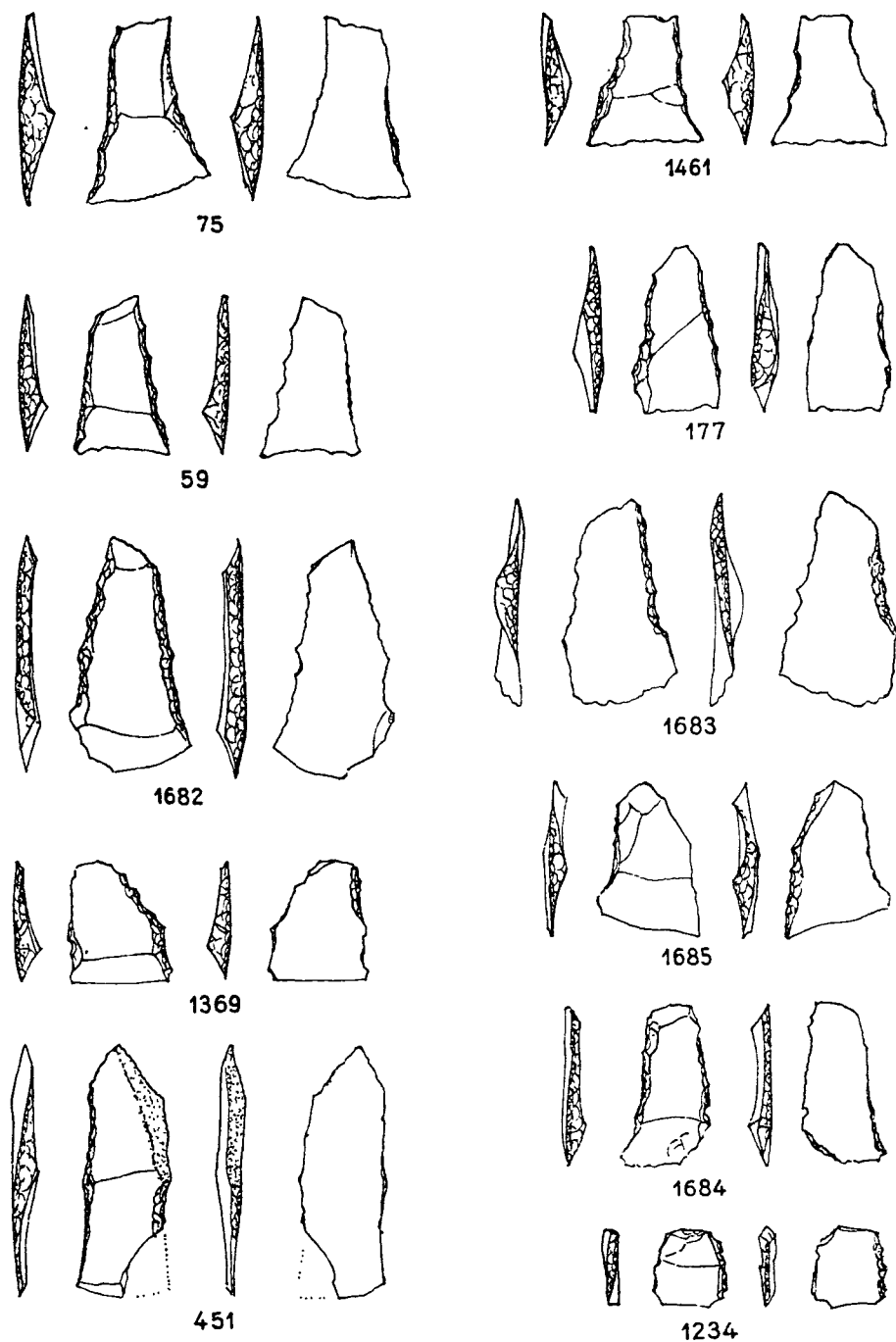


FIGURE 12.—Transverse arrowheads made from blades and flakes. (Scale: fig. 75=2.5 cm.) (Drawings by A. Noll Sørensen.)

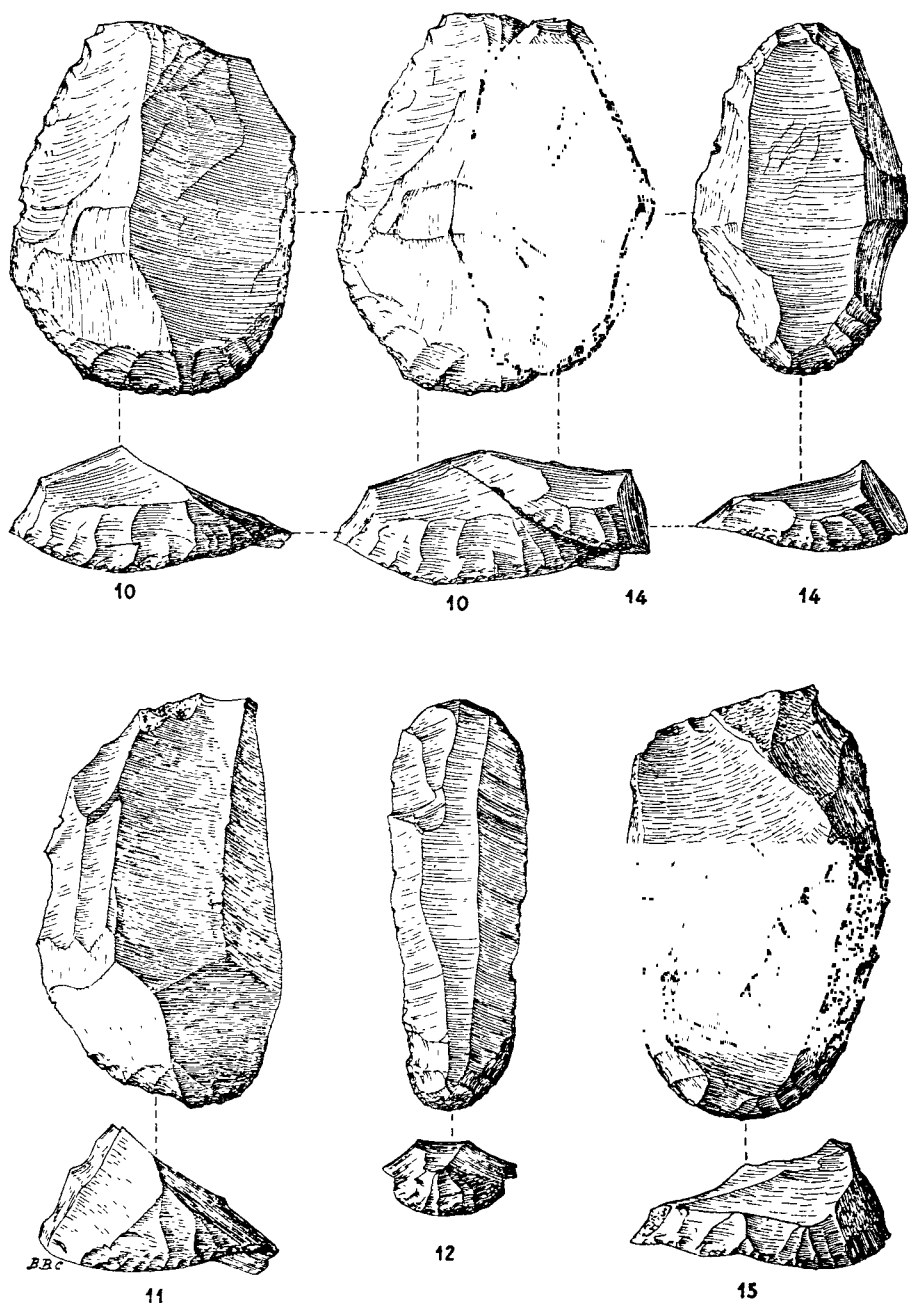


FIGURE 13.—Scrapers of various types: 10, Discoidal; 14, oblong; 12, typical blade scraper. The scrapers 10 and 14 are made from two "discs" flaked off one after the other. (Scale: fig. 10=7.2 cm.) (Drawings by B. Brorson Christensen.)

RADIOCARBON DATING

For many years pollen analysis was the most accurate method of dating prehistoric finds, but in recent years, as a byproduct of research in nuclear physics, a dating technique has been developed which, earlier, one would not even have dared to dream of. By this radiocarbon method it is possible to give the age of organic materials, i.e., wood, bones, horn, plants, etc., in years. The principles and the application of this dating method will not be dealt with here, but it may be mentioned that the Muldbjerg dwelling place has provided material for a long series of radiocarbon dates. The dating of this dwelling place thus is among the most accurate obtained so far. It appears that Muldbjerg was inhabited around 2830 B.C.—possibly up to 80 years before or after this date; i.e., most probably between 2750 and 2910 B.C. As all finds indicate that the dwelling place was inhabited for only a single summer, the year of this occupation most probably falls within the above-mentioned interval (fig. 17).

THE MULDBJERG DWELLING PLACE AND THE PEOPLE WHO LIVED THERE

We do not know what the people who lived on the floating island looked like. Judged from contemporaneous finds of human skulls and bones, there is reason to believe that both men and women were rather small, respectively about 165 and 155 cm. tall, relatively slight, and with dolicocephalic skulls. At the islet they were living in a hut about 6 to 7 meters long and hardly 3 meters wide, and with its long axis east-west. Along each side 6 to 7 hazel sticks were put down; the pointed ends were found 15 to 20 cm. below the upper culture layer. It would be reasonable to imagine that the hut was covered with reeds, although we have no observations indicating this. In the hut itself large amounts of charcoal and flint chips were found. Outside the hut, along the north side, no culture remains were left; on the other hand, fireplaces and numerous tool finds indicate that the south side was the preferred place to sit, where there was a view over the lake. Here the women could sit and watch when the men came home from hunting and fishing in their dugouts, and here the men sat chopping their flint tools, flake axes (fig. 15), and core axes. They also had polished, point-buttet axes. With their flint knives (fig. 14) and discoid scrapers (fig. 13) they were able to carve and shape wooden tools with great skill. Thus arrow shafts carved from ash wood were found, and from alder they produced nicely formed spoons, as is shown by a specimen found at a neighboring contemporary dwelling place (pl. 3, fig. 2). Discoid scrapers were used for skin preparation, and for sewing they probably used pointed awls of bone.

The study of a number of small, pointed flint pieces has given valuable information about the manner in which flint drill points were manufactured (fig. 11). They were difficult to produce, and,

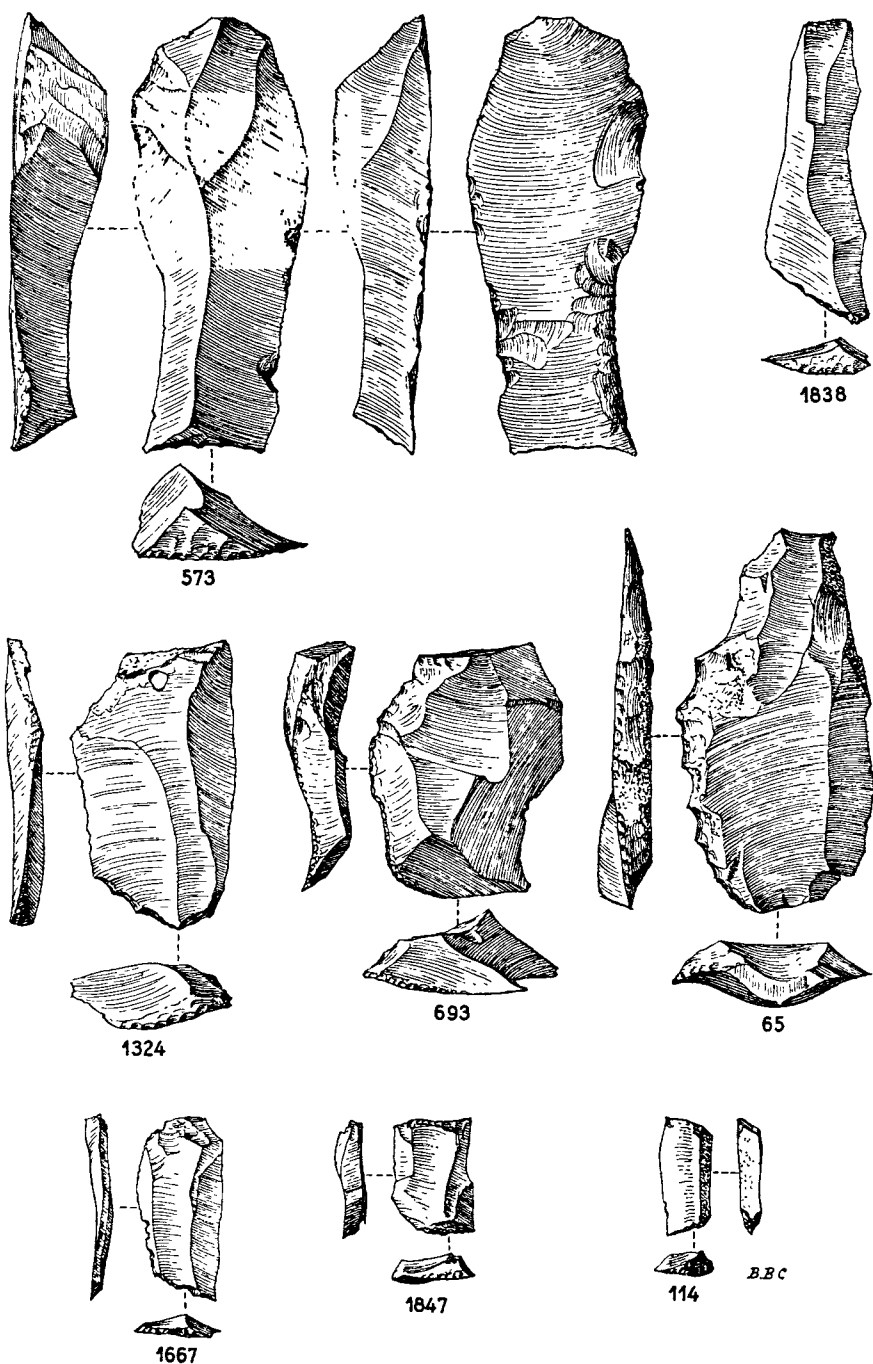
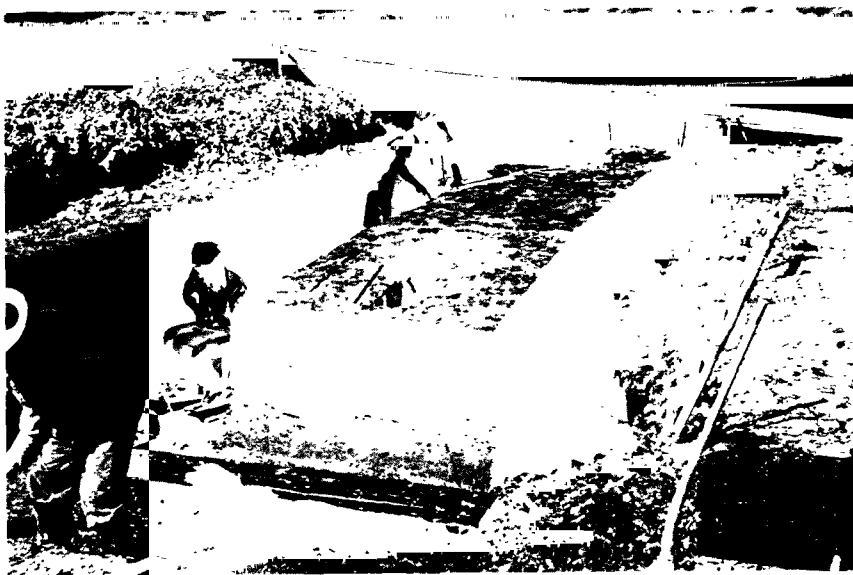


FIGURE 14.—Various types of knives, characterized by the blunted back. (Scale: fig. 573=8.5 cm.) (Drawings by B. Brorson Christensen.)



1. The Muldbjerz dwelling place during the excavation. Behind the excavation, peat litter is being collected for the manufacture of briquettes.



2. A peat block, cut clean and drained, is being excavated.



1 Excavating and surveying culture remains. The coordinates are recorded, and after being leveled out the finds are numbered and tagged and wrapped in paper.



2. The peat islet "Store Holm" in lake Lyngby Sø, 10 miles north of Copenhagen. Most of the islet is floating on the water and is only 40 cm. thick. The Muldbjerg dwelling place must have looked much like this. (Photograph by Lennart Larsen.)



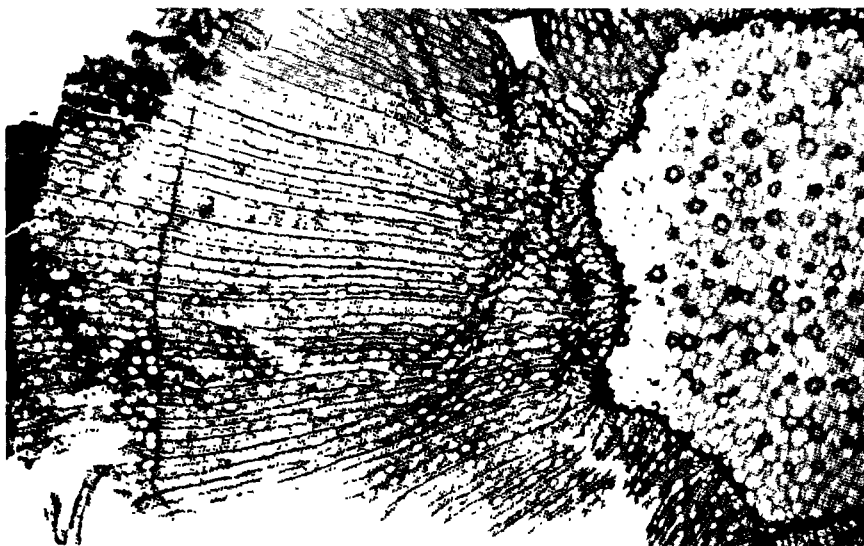
1. Metatarsus of red deer, split in order to get out the marrow; 19 cm. long. (Photograph by Lennart Larsen.)



2. Spoon carved from alder wood, 30.6 cm. long. The spoon had cracked and had been repaired by drilling holes on both sides of the crack and tying the parts together with bast string. This object was not found at the Muldbjerg dwelling place, but at a neighboring dwelling place of exactly the same age (Maglelyng XL). (Photograph by Lennart Larsen.)



1. In the exposed culture layer 700 twigs of hazel and willow were found placed together in bundles. All the twigs were between 1 and 2 years old. (Photograph by Lennart Larsen.)



2. A section of willow twig, magnified about 40 times. To the extreme left the black bark layer is seen. Next follows a relatively small, not full-grown year ring (the uncompleted second-year ring). Then follows the ring from the first year; and at the extreme right, the pith. (Photograph by E. Tellerup)



a, b, Sherd from a funnel-necked beaker of A type with finger prints in the reinforced rim. 7.2 cm. high. *c, d*, Very thin-walled vessel from the Muldbjerg dwelling place, seen in profile and from the front. 6.6 cm. high. (Photograph by Lennart Larsen.)



a, b. Pierced cord handle belonging to a lugged vessel found at the dwelling place. 5.6 cm. high. *c.* Vessel with pierced cord handles for suspension. The vessel was found in the lake sediments about 80 m. north of the dwelling place. Pollen analyses have shown that it is contemporary with the dwelling place. 19.3 cm. high. (Photograph by Lennart Larsen.)



FIGURE 15.—Flake ax, the most common type of ax at the dwelling place. $\frac{3}{4}$ size. (Drawing by B. Brorson Christensen.)

therefore, they often broke during the process of manufacture. In some cases we have succeeded in fitting together the broken pieces of more or less finished drill points. In this way it has been possible to obtain a sort of slow-motion picture of the manufacture. First, one finds small flint blades chipped along one side; next, pieces chipped along both sides; then others in which the point has been finished but not yet worn by use; next, finished pieces which were broken in use; and finally, pieces which had been used for so long that the point was worn down and the blade, therefore, rejected. Only a small percentage were used for this length of time. An amazingly great number has been found, but for what purpose were they used? Some of the artifacts themselves give the answer.

A wooden spoon had cracked and had been made usable again by drilling a hole on either side of the crack and binding it through the holes (pl. 3, fig. 2). Also some of the earthen pots had broken and had been repaired by drilling holes on both sides of the crack, tying the parts together with lime-bast, and smearing birch tar and resin over the strings and holes.

It is an established fact that people of that time used birch tar. This is known partly on account of the repaired vessels, and partly from a single pot which contained a 1-millimeter-thick layer of birch tar on the inner side. It is possible that the many rolls of birch bark, which were found in the culture layer, indicate that birch tar was burnt at the place.

The bone finds tell that, apart from fish, the people ate wild boar, beaver, and roe deer, and, less often, red deer. Accordingly, it must have been hunters who lived here. At the same time strawberries, raspberries, and hazel nuts were eaten to a great extent. However,

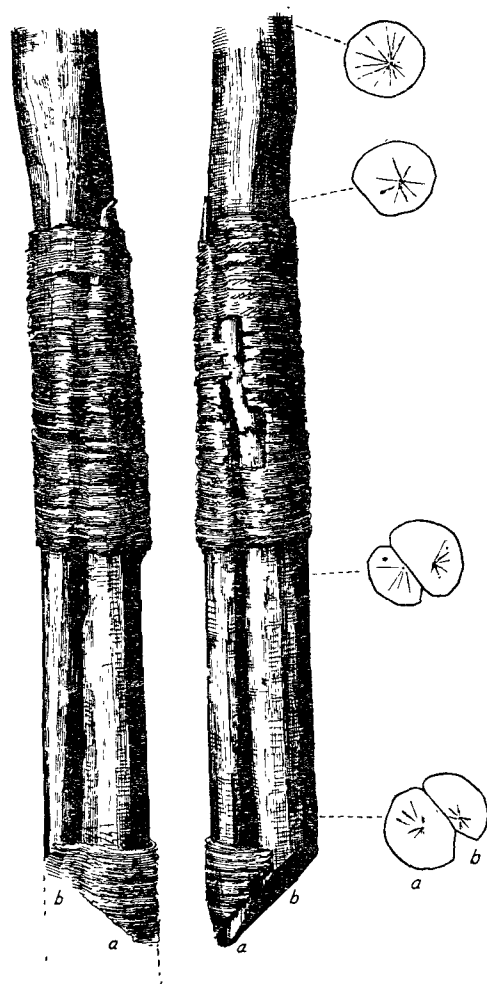


FIGURE 16.—Two hazel sticks lashed together with bast string; 31 cm. long. (Drawing by B. Brorson Christensen.)

a few finds indicate the beginning of a new epoch. A few bones of domesticated cow and sheep thus were found, and one of the potsherds had an impression of a wheat grain. It is inconceivable that cattle were kept and cereals were grown on the floating island. The picture we get of the family, or families, who lived on the island during the months of June to September, therefore, is the following:

At the coast, probably the Great Belt, they had their permanent dwelling place, and there they had a small field in a glade where they grew cereals. Close to the residence they presumably had a few cows and sheep, tethered or kept inside an enclosure. There is no indication of pastures at that time; presumably the animals were fed with

leaves, as they are to this day in remote parts of Europe. Still, hunting and fishing were the main occupations. We may imagine that the women cared for the household, and that the field was sowed by them—nobody else knew better that the hunter's luck could fail. It was the men who hunted seal and sea birds at the coast, and in the summertime the fresh waters called with fish and duck—and the wanderlust lived in them.

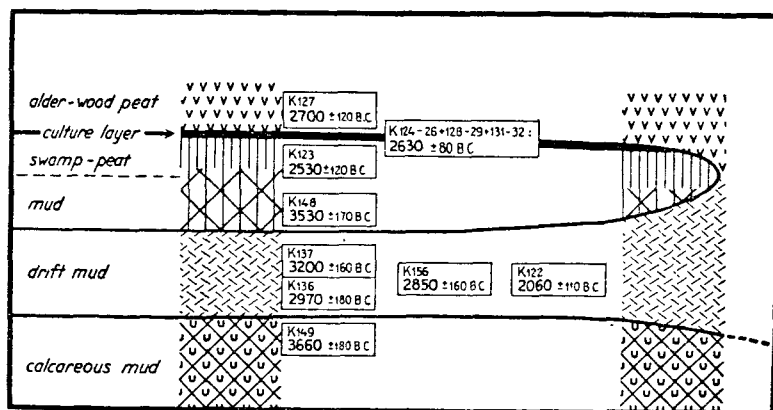


FIGURE 17.—Schematic section through the dwelling place on the floating peat island. K-123, etc., are the numbers of the carbon-14 samples. All dates given are B.C. According to a correction from the radiocarbon laboratory all dates should be 200 years older.

Three Adult Neanderthal Skeletons From Shanidar Cave, Northern Iraq

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[With 12 plates]

THE RECOVERY of three adult Neanderthal skeletons in Shanidar Cave, northern Iraq, by the Third Shanidar expedition in 1957 provides important new data for the study of Early Man. This archeological expedition, sponsored by the Smithsonian Institution,¹ made further contributions to our knowledge of the early cultures of Iraq, preliminary announcements of which have been published (Solecki, 1957a, b, c, d, 1958, 1959a, b; Solecki and Rubin, 1958).

The purpose of this paper is to describe the circumstances of the discoveries of the Neanderthal skeletons; to indicate their stratigraphic relationships to one another and their positions in the cave deposits; and to provide such information on the individuals represented as could be interpreted from the archeological remains. A provisional correlation is made between the Shanidar skeletons and other Middle Paleolithic skeletons in the Near East. The morphological descriptions of the Shanidar Neanderthals are left to my colleague Dr. T. D. Stewart, of the U.S. National Museum, Smithsonian Institution. In his special field, Dr. Stewart has assumed the obligation of the restoration, description, and evaluation of these Mousterian age remains (Stewart, 1958, 1959).

¹The Third Shanidar Expedition was supported by grants from several organizations, including the American Philosophical Society, the William Bayard Cutting Traveling Fellowship of Columbia University, the National Science Foundation, the Bruce Hughes Fund of the Smithsonian Institution, and the Wenner-Gren Foundation for Anthropological Research. The Iraq Petroleum Co., Ltd., graciously lent material aid and assistance to the expedition in Iraq. The Directorate General of Antiquities of Iraq, as in the 1951 and 1953 seasons, extended its cooperation. The work of these seasons has been published in preliminary statements and reports (Solecki, 1952a, b, 1953a, b, 1955a, b, c; microfilm). The field personnel of the Third Shanidar Expedition included the author and his wife, Dr. Rose J. Solecki, archeologist of Columbia University; Philip Smith, archeologist of Peabody Museum, Harvard University; and George Maranjian, physical anthropologist, of the Arabian-American Oil Co. at Dhahran, Saudi Arabia.

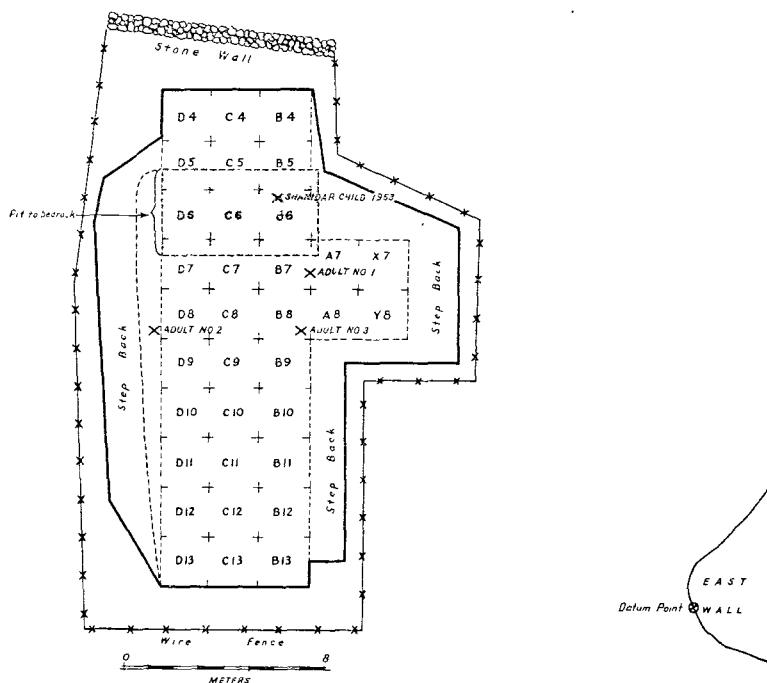


FIGURE 1.—Ground plan of the Shanidar Cave excavation, 1957 season.

The excavation in Shanidar Cave wherein the Neanderthals were found now measures 20 m. long by 7.75 m. wide at the top (fig. 1). It is stepped back in depth toward the bottom, where bedrock was reached at a depth of nearly 14 m. Four major cultural layers were outlined in the deposits (Solecki 1955a, b) (fig. 2). These deposits, from top to bottom, were identified as Recent to Neolithic (Layer A); Mesolithic (Layer B); Upper Paleolithic, or Baradostian (Layer C); and Middle Paleolithic, or Mousterian (Layer D).

During the three seasons of excavation, the skeletons of seven individuals, including the three described here, were found in Shanidar Cave. Three skeletons were found in Layer A, and four were found in Layer D. The latter include the adult Neanderthals and an infant found in 1953 (Solecki, 1953b, 1955a, b, c). The infant remains were studied in Baghdad by Dr. Muzafer Şenyürek (1957a, b, 1959) of Ankara University during the winter of 1956. The Shanidar child was found at a depth of 7.8 m. The three adult Neanderthals were found above this depth, toward the top of the same deposit, Layer D.

SHANIDAR I

The circumstances of the discovery of Shanidar I (field catalog No. 504 III) were as follows. There had been some trouble with loose

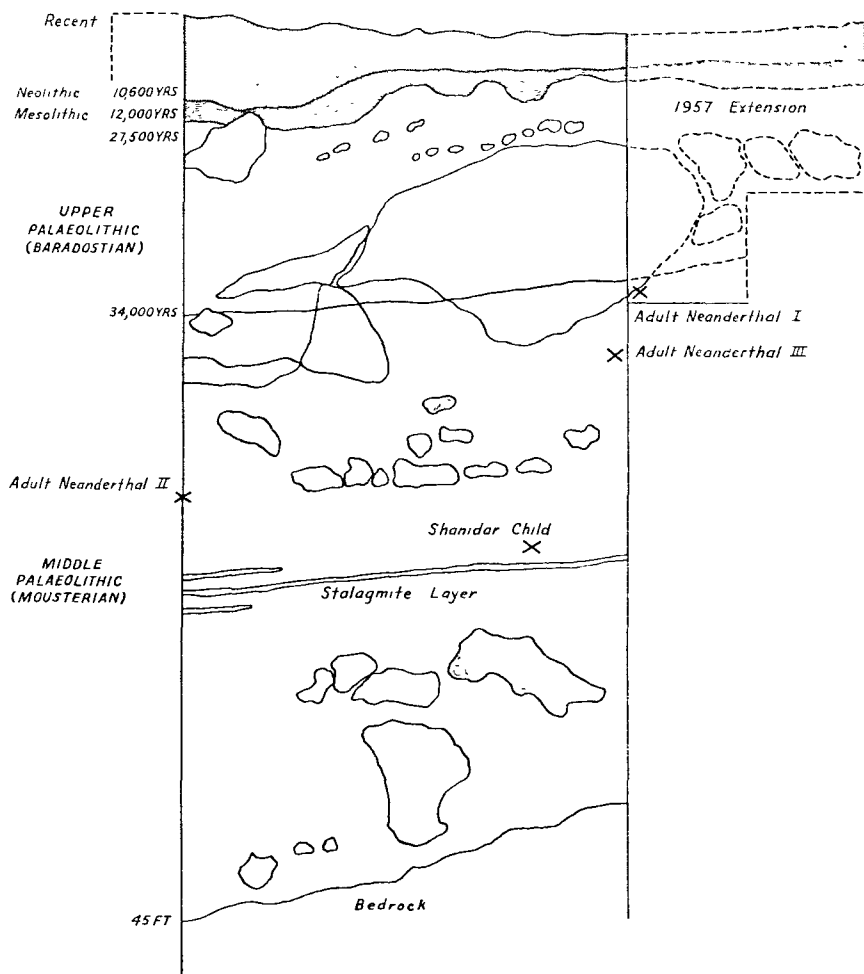


FIGURE 2.—Schematic cross section of the Shanidar Cave excavation.

stones falling into the excavation from Layer A. While this condition was being corrected, it was decided as an additional safety measure to remove a bulge of earth near the top of the eastern wall of the excavation. On the day of the find, April 27, a rainy Thursday, Philip Smith took a turn with the full labor force to work at Shanidar Cave. At the same time I took advantage of a free day and the services of Michael Mansell Moullin, an engineer then employed by the Iraq Government, to survey the Zawi Chemi Shanidar site close to Shanidar village.

In my notes of April 27 I recorded that "at tea time, Phil reported the calvarium of a man in the Baradost layer—material from layer

included Baradostian flints." Smith's notes record the following data: "In afternoon while cleaning off east profile just over B 7, found human skull under rocks at depth 4.34 meters. No signs of burial except for thin dark streak on west side of skull. Skull faces south slightly tilted on right side. Large stone resting on top of skull when found (not photographed at this period). Surrounding earth yellowish brown clayey dirt. Heavy rocks above and all around—possibly the individual was crushed in rockfall, or lay in very shallow grave on which rocks fell. All cranial bones seem present although crushed. Rather heavy brow ridges."

Further facts regarding this discovery are as follows. In order to trim the bulge in the excavation wall, Smith put two of our most powerful workmen to cleaning away some overhanging stones and earth. They took to this task with great energy, recklessly tearing out huge chunks of soil and letting them fall down into the pit. Smith noted this with disapproval and assigned Adai, our Arab Shergati archeological assistant, to this job. The two pick wielders were given another task where they could not harm themselves, their neighbors, or anything in the ground.

The assistant had been at work about 5 minutes, when at 1:30 p.m. he struck a bone with his light pick. Putting this bone aside carefully and taking up his trowel, he cleared an area to see where the bone came from. In so doing, the top of the skull vault or calvarium emerged. This was the moment of discovery. He cleaned it off enough to be sure that it was not a stone, then beckoned to Smith, who had been watching his actions closely, to look at what he had unearthed. It was a reddish-brown dome of bone, with a natural, flat, loaf-shaped limestone slab resting on its top rear. The stone was roughly triangular in shape, measuring 25 by 25 cm. and 10 cm. thick. There was a thin layer of earth between the stone and the skull cap. Smith cleaned around the skull and at the day's end, covered the exposed calvarium with a small hand screen and a burlap sack as protection for the night. Our two night guards were instructed to keep careful watch over the specimen till the next day. When Smith casually mentioned that evening that a skull had been discovered at the cave, we were somewhat skeptical. It was a very great surprise, as well as a new responsibility.

The following morning, April 28, the expedition staff, including Rose Solecki, Philip Smith, George Maranjian, and our guest, Michael Moullin, and I went up to the cave to see the find. The representative of the Directorate General of Antiquities, Sabri Shukri, was away at the time. My initial impression of the discovery as entered in my notes that day were, "A Neanderthal if I ever saw one." We had a lively discussion about it during supper.

When first seen, the top of the skull was a small thing perched on the eastern edge of the yawning excavation and lost in the gloom of the huge cavern (pls. 1, 2). It was difficult to realize at first that we had an extreme rarity in human paleontology before us. It looked like an earthy-colored protuberance at the very end of a narrow ledge in a sheer wall of stones and earth. The stark whiteness of the limestone blocks and the fragments of rocks around it contrasted sharply with the fresh brown-colored soils in the section, crisscrossed by pick marks. Seen more closely, and except for the just emergent heavy brow ridge, the skull cap looked like a very soiled and broken gigantic egg. It lay in the southeast quarter of square B 7, at a depth of 4.1 m. from the cave surface at that point, or 4.34 m. below "0" datum² (fig. 3). The skull faced to the south toward the cave entrance, about 13 m. away. Some broken limestone rocks jutted out near it. A preliminary survey showed that the shaft of my 1953 season excavation had missed the skull by a scant 25 cm., an extremely small margin.

It was very hard to visualize this heavy-browed skull as belonging to modern man, as expected if the find were really in the Upper Paleolithic Baradostian layer as recorded by Smith. A recheck of the stratigraphy showed that this observation was in error because of the rockfalls in this quarter. Actually the skull lay in the very top of Layer D, the Mousterian layer.

It was noted that the find lay about 2.75 m. to the north, slightly to the east, and 70 cm. above a collection of then unidentified bones (field cat. No. 384 III) (pl. 1). The latter were exposed in the northeast quarter of square B 9. These bones were being cleaned and readied for photographing and drawing.

Above the thin bed of moist soil in which the skull lay was a 40-cm. thickness of limestone rockfall, consisting of broken blocks, above which in turn was a solid block of limestone about 50 cm. thick. The notch or shelf in which the skull lay was barely large enough to hold three people standing in single file. Only one person could conveniently work on the skull at a time.

Actually the skull rested in one of three closely spaced thin occupational strata. These lay within a discontinuous thickness of rockfalls extending between the depths of 3.5 to 5.5 m. below "0" datum at that point. The stones of the rockfalls were shattered and broken, intermingled with patches of light-gray powdery rock meal. Some of the soils may have washed in or drifted in following the rockfalls. Immediately above the approximately 1.0-m. thickness of rocks above the skull was a dark-brown loamy soil layer between 75 and 125 cm. thick, identified as Layer C. It contained heavy occupational evidence, including Baradostian flints.

² Unless noted otherwise, all depths are given from "0" datum.

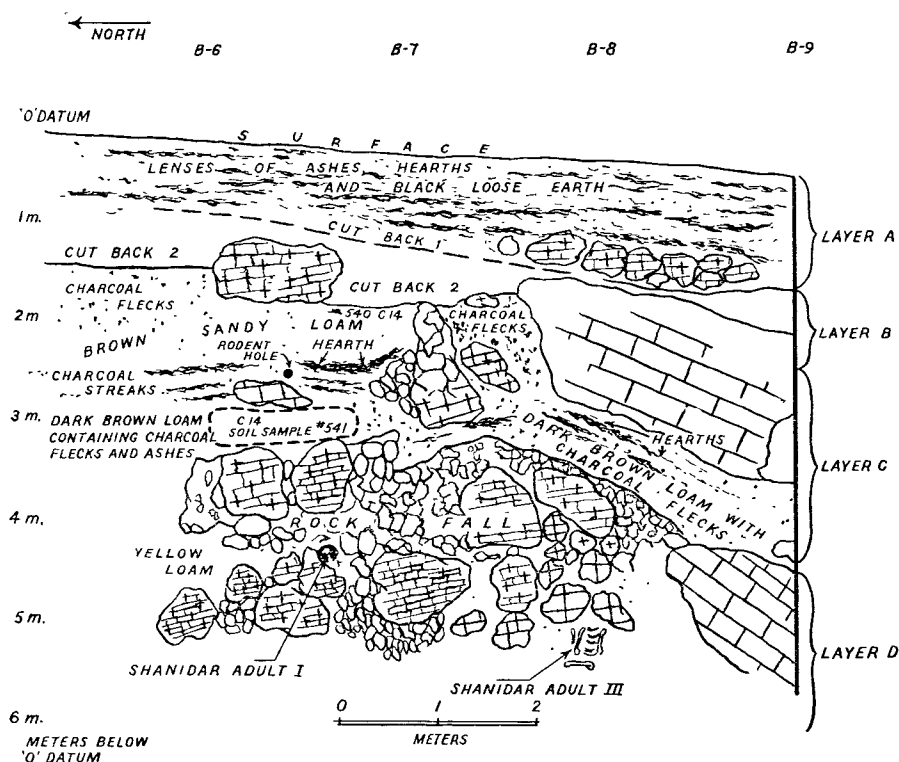


FIGURE 3.—Cross section of the east wall on line B6-B9 showing the location of Shanidar adult skeletons I and III.

Before any further cleaning was done around the skull, a careful appraisal of the situation was made. It was too hazardous to enlarge the cut because of the heavy limestone blocks above and all around the find. Limestone fragments were found as close as 10 cm. to the east side of the skull. It lay in a pocket of loose, moist, dark-brown sandy loam containing some charcoal flecks. A broad, oblong, horizontal streak of dark soil measuring 8 cm. long and 1 cm. wide was encountered about level with the eyebrows and 5 cm. from the west or right side of the calvarium. This streak, containing charcoal flecks, extended downward along the side of the skull parallel with its axis, widening to a width of 3 cm. It may have been part of a rodent burrow, a fairly common phenomenon in Shanidar Cave. Soil samples were taken from around the skull as the work progressed.

We naturally wondered how much of the rest of the skull, including the face, was preserved below the eyebrows, and further cleaning resolved this question. It was evident that the blow on top of the skull

had caused much damage to the lower part. The nasal bones were broken and bulged outward. The skull height was foreshortened, measuring about 10 cm. from the top to the level of the brow ridges. However, even in its crushed state, the cranial vault appeared to have a definitely sloping forehead behind a heavy brow. The skull was canted slightly to the west, although still on an even keel. It faced south by southeast.

Approximate field measurements were made on the skull using a wooden rule. The head length was about 21 cm., breadth about 18 cm. These measurements on the crushed skull of course did not represent the original skull dimensions. The biorbital diameter was about 12 cm. The brow ridges were very prominent and striking; they did not form a complete torus between the eyes, and they had a definite lateral flare. They measured about 12 cm. from side to side. Just behind the brow ridges was a marked postorbital constriction. A bulge occurred in the region of the facial bones on either side of the nasal aperture. A fragment of unidentified bone protruded from the orifice of the left eye socket. The frontal bone was cracked just to the left of the midline, the crack arcing up over the left brow. There was a vertical break through the middle of the left brow (pls. 3, left, and 4, upper).

The condition of the breaks in the calvarium could be accounted for only by the crushing blow on the rear of the top and left side of the head, which burst the sides asunder. All the cranial bones seemed to be present and accounted for. The right part of the cranial vault, including the broken parietal, appeared to be in good condition. The bones of the left side of the skull vault just behind the frontal bone had been collapsed deep into the skull, leaving a V-shaped, jagged break (pls. 3, right, and 4, lower). An area measuring 15 cm. long and 10 cm. wide was crushed in the cranium. Fragments of limestone were picked out of the loose dark-brown soil filling the top of the cavity. Part of the right upper parietal shelved over the break. All the sutures of the skull appeared to be closed, giving evidence of full maturity.

We were very much impressed by the freshness of the appearance of the bones. They were dark reddish-brown, with black mottled patches and specks scattered over the surface. Although the bones were very friable, they were in a fair state of preservation and the soil peeled away very easily, leaving a damp surface, which dried rapidly on exposure. During the cleaning operation, an important consideration for the preservation of the skull became apparent. It seemed that the firm exterior surface of the cranial vault belied the actual thickness of the bone, particularly the crushed-in part of the left side (pl. 4, fig. 2). There the bone was reduced to almost eggshell thinness because the inner bone surface had become detached. Maran-

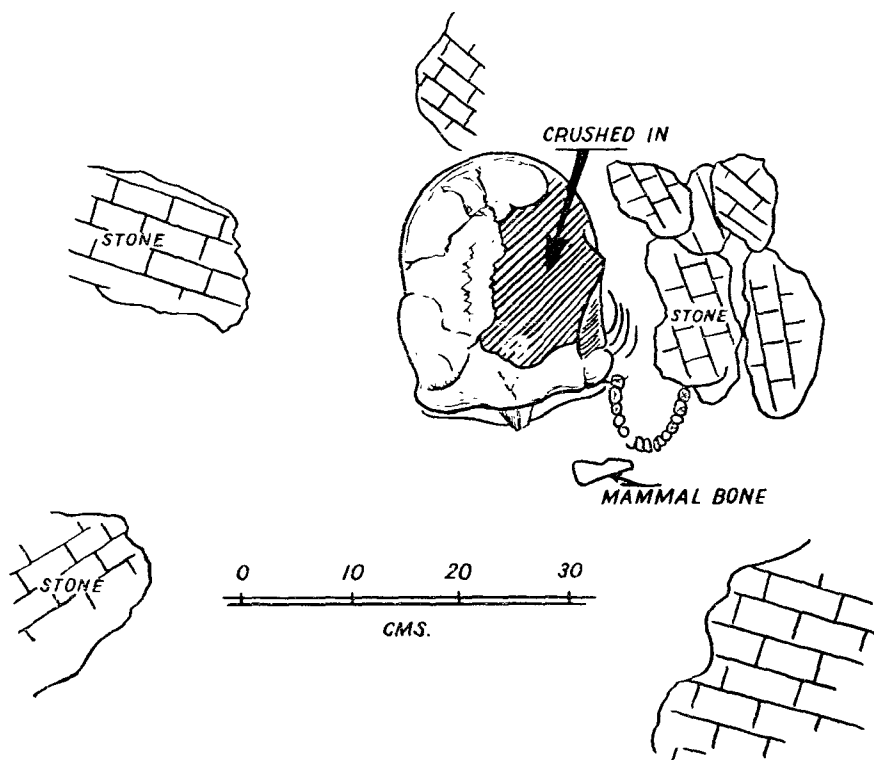


FIGURE 4.—Top view of Shanidar adult Neanderthal I.

jian's careful attention later in the Shanidar laboratory prevented further deterioration of this sort.

Probing around the lower part of the face revealed that the lower jaw or mandible was missing from its expected position. In the course of cleaning away the soil, a U-shaped row of blunt projections showed up to the left and front of the face. Further cleaning exposed a row of teeth in a mandible, for such it was (pl. 3 and fig. 4). A flat stone lay firmly under it. Like the cranium, the lower jaw was canted to the west, but at a slightly greater angle. A definite chin was lacking. The mandible had been distorted, undoubtedly by the same force that struck the skull. The left side of the mandible had been pushed forward and inward. The right ascending ramus was not seen, and was judged to be lodged in the cranium. The left ascending ramus was freshly broken, but the detached part was still present. It was here that the Shergati assistant had initially encountered the remains. This ascending ramus appeared to be fairly broad, with what impressed me as a rather shallow sigmoid notch.

All the teeth, with the exception of two medial incisors, seemed to be present. There was a small gap between the right canine and the first right premolar, probably due to a fracture in the mandible. The

teeth were worn down flat and fairly even, with no protrusion of the canines. The lower and upper front teeth exhibited curious wear. They were rounded from front to rear. The third molar seemed to be slightly larger than the second, and the latter in turn was slightly larger than the first.

Below, but to the front and right of the lower jaw, was a bone fragment that looked like a piece of ordinary mammal bone. It was darker in color than the skull.

Parts of the postcranial skeleton could be seen projecting out of the earth below and to the east of the lower jaw. Immediately to the east and touching the jaw was a slab of flat, rotted limestone of then undetermined dimensions. The stone lay between the skull and the presumed remainder of the skeleton proper. Further cleaning exposed the neck or cervical vertebrae in the angle between the lower jaw and the skull. The vertebrae, the first apparently still articulated with the skull, were contorted up to about the lower level of the eye sockets, then arched downward to the left side of the skull. The slab of limestone noted above cut the neck vertebrae at the fourth cervical. What appeared to be a collar bone or clavicle jutted out of the earth next to the vertebrae.

The soil around the lower part of the face was a dark-brown sandy loam, containing flecks of charcoal, bits of limestone, and small fragments of bone. Thirty-five cm. to the west of the skull, close to the edge of the excavation, was a small hearth consisting of ashes and charcoal. This hearth was undoubtedly contemporaneous with the individual's remains.

When fully exposed in its niche on the narrow excavation shelf, the skull made an awesome sight. It was obvious to even the most casual of viewers that this was the head of a person who had suffered a sudden and violent end. The bashed-in head, the displaced lower jaw, and the unnatural twist of the neck were mute evidence of a horrible death. My deduction that this was an antemortem, and not a post-mortem, accident is based upon the observations that the head, neck, and lower jaw, although greatly disturbed, still formed a unit, as though originally joined by flesh. The broken bones of the skull vault indicated that a sudden compression of a filled skull had caused it to burst at the sides.

It was apparent that the rest of the skeleton lay to the east under tons of earth and stones at the same depth as the skull—over 4 meters. The uncovering of the postcranial skeleton presented an excavation problem for which two solutions were possible. The first was to remove the skull, then uncover the postcranial skeleton without fear of damage to the skull. The alternative was to seal the skull in place under a protective matrix, uncovering the entire skeleton as a complete unit. The latter method was attractive, since, when exca-

vated, the whole skeleton could be examined in situ. However, after considering the dangers and risks of this plan, I decided on April 28, to remove the skull before attempting to dig down to the skeleton. In the removal of the overburden, some stones would certainly fall down the side of the excavation and possibly cause the wall to slump down carrying the skull with it. Furthermore, the necessity of using explosives to remove several boulders above the remains was foreseen. Actually three blasts were set off on May 11.

In removing the skull, the most expedient means seemed to be to take the cranium and mandible out as a unit in a shell of plaster of paris, rather than try to remove each separately. The whole casing, when finished, looked like a huge egg, 76 cm. long and 45 cm. in diameter, nestling on the ledge. It was placed in a strong padded box provided with two long poles nailed securely on each side for carrying. On April 29 two men transported the priceless burden down to the waiting vehicle at the base of the mountain trail. The skull was unpacked at our field laboratory in the Shanidar police post and turned over to Maranjian. He gave it painstaking attention, cleaning it, mending breaks, and preserving it from further deterioration.

Before any work was done to expose the skeleton, a number of observations were made on the profile of the cut, and photographs and sectional drawings were made. It was evident that the remains of Shanidar I had been sealed in an occupational stratum between two separate rockfalls, as in a trap. The earlier of the two rockfalls was represented by a layer 90 cm. thick. Shortly after reoccupation of the site following this rockfall, perhaps only a few hundred years later, there was another rockfall, dislodging about the same thickness of stones as earlier, killing our unfortunate Shanidar I man. The debris of stones sloped downward from east to west. The top of this covering above the skeleton was about 3.5 m. from the surface.

It was decided to remove the overburden above the postcranial skeleton by incorporating the work in our established excavation grid system (fig. 1). The remains lay in the southern half of square A 7. The grid was extended over the area in four 2-meter squares, A 7, X 7, A 8, and X 8. The layers were excavated for convenience and control in levels of 25 cm.

After Layers A and B were stripped off, a heavy occupational zone of the Baradostian layer (Layer C) was found to extend to a depth of 3.5 m., or to the upper boundary of the heavy rockfall deposit. The Baradostian peoples seem to have adjusted the cave floor to suit their needs, as there were abundant signs that parts of the floor had been scooped out and modified. Some flint flakes and fragmentary mammal bones were recovered at a depth between 3.5 and 3.75 m. indicating that some material probably filtered down through crevices in the rocks from above. An increase in the amount of yellow-brown

soil with many fragments of limestone and rockmeal was observed in the 3.75–4.00 m. level. Some fragmentary bones, provisionally identified as mammal, were found at this depth. A hearth was observed in the northwest part of the section. In general, at a depth of 4.00–4.25 m., still above the skeletal remains, the soil was a yellow-brown sandy loam and contained many limestone fragments. Fragmentary mammal bones, some of which showed traces of burning, were noted and collected. At a depth of about 4.15 m., directly over the skeleton, in the left-central part of square A 7, there were a number of smaller-sized limestone rocks loosely clustered together in an ovate heap (fig. 5). They consisted of angular, blocky, portable-sized stones, constituting a loose group when compared with normal rockfall concentrations. The soil among these stones was a loose brown sandy loam, forming a contrast with the yellow-brown sandy loam above. I raised the question early in my notes whether these stones were part of a rockfall or were intentionally placed over the skeleton. Rockmeal, usually associated with rockfalls, was absent. Altogether the stones over the skeleton weighed probably not more than a couple of tons. It looked like an unusual pocket of smaller stones among a lot of larger stones—a cluster superimposed upon a layer.

The area to the immediate north and sides of the cluster appeared to be relatively clear of stones, as though they had been removed and piled in a heap. The soil just to the north of the heap of stones was a very dense and compact yellow loam, which contrasted with the brown loose soil in the stone covering. The yellow loam contained occasional flecks of charcoal, perhaps washed in from above.

The stones just to the south and southeast of the heap were part of the compact layer, with no brown soil between them. Instead, the soil around these massive blocks was composed of rockmeal. Unlike the stones in the heap, these stones were removed with considerable difficulty.

When the first few stones were picked off the heap, it was found that a number of well-preserved but fragmentary mammal bones were scattered among them (fig. 6). These included two ribs, some vertebrae, and several incisors. A large unidentified bone lying to the northwest and at a slightly higher elevation than the skull had been squashed as flat as tissue. Some flint flakes also were recovered, among them one which was broad and had a faceted basal platform; this was a Mousterian type.

There were abundant indications that Shanidar I was associated with an occupational horizon. The bones lay on a dark-brown soil zone containing flecks of charcoal, fragmentary mammal bones, and flint flakes. Under the skeleton this layer measured 10 cm. thick. Below this the soil changed sharply to a lighter brown color. At least two hearths were found just below the skeletal remains. One



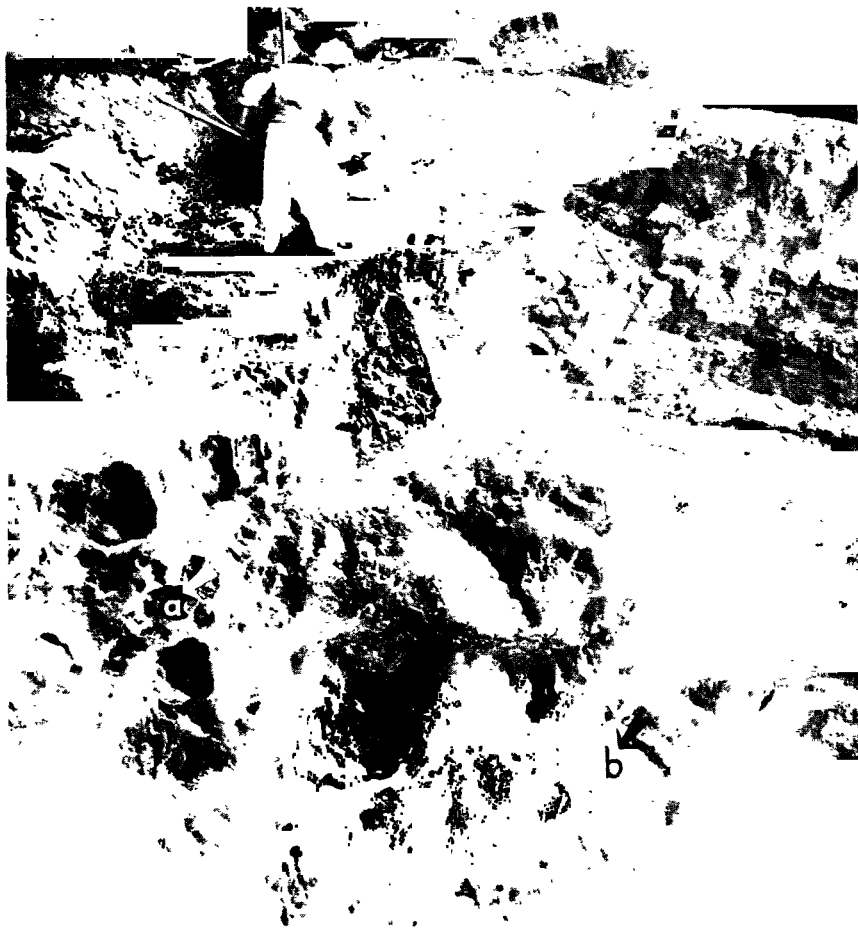
FIGURE 5.—Heap of stones lying over Shanidar adult: Neanderthal I.

of these, under the right leg, was evidenced by a concave-sectioned streak of burned earth and charcoal 12 cm. long and about 3 mm. thick. Another carboniferous soil streak was found just to the north of the left forearm.

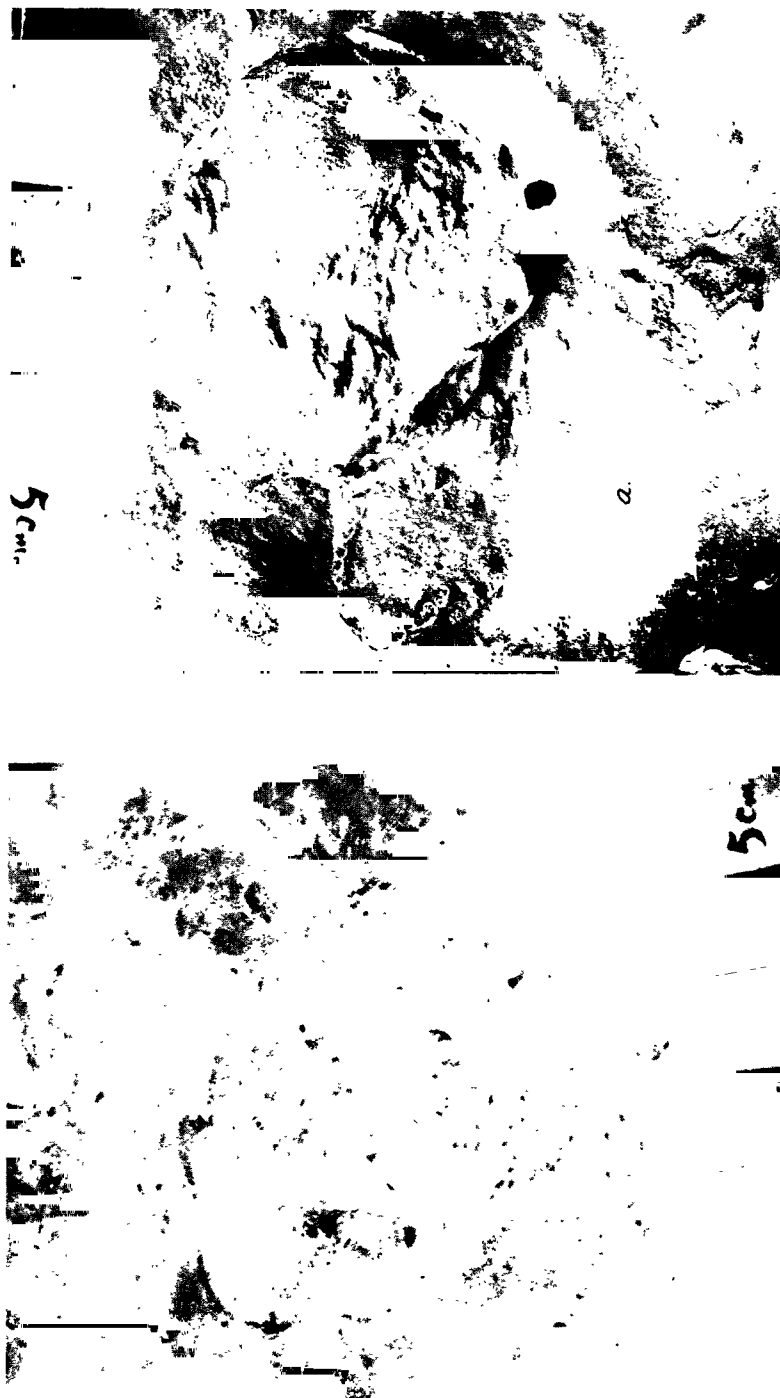
As we exposed the skeleton, there was increasing evidence that this individual had been killed on the spot by a rockfall. Bones were observed to be broken, sheared, and crushed. Some stones were in direct contact with the bones. Various parts of the skeleton thus



Recording the discovery of the skull of Shanidar I (a). The stone found over the skull is before it. The workman with the Arab headdress, standing by, discovered this find in the east wall of the excavation. Philip Smith, on the ladder, is taking notes. George Maranjian is taking a photograph. Shanidar III (b) is being exposed 2.75 m. away from Shanidar I



Clearing away part of the loose earth above the skull of Shanidar I, temporarily covered before removal (*a*). It was found at a depth of 4.1 m. below the surface, or 4.34 m. below "0" datum in the top of the Mousterian layer. The find spot of Shanidar III (*b*) was at a lower level, 5.0 m. below the surface, or 5.4 m. from "0" datum. The successive rockfalls are shown. The step in the excavation wall at the lower left indicates the boundary of the 1953 season excavation, showing by what a small margin the skull of Shanidar I was missed that season.



The skull of Shanidar I. *Left:* Viewed from above and front. It was found under a stone, which had crushed in the left rear part of the skull with considerable force. The cranium had been sheared off from the lower jaw and the neck vertebrae were twisted. The postcranial skeleton lay to the right. *Right:* Viewed from the top, showing the displaced lower jaw, the twisted neck vertebrae, and the crushed state of the left rear side of the skull. The unusual wear on the front teeth may be seen. A limestone slab (a) lay over part of the postcranial skeleton.



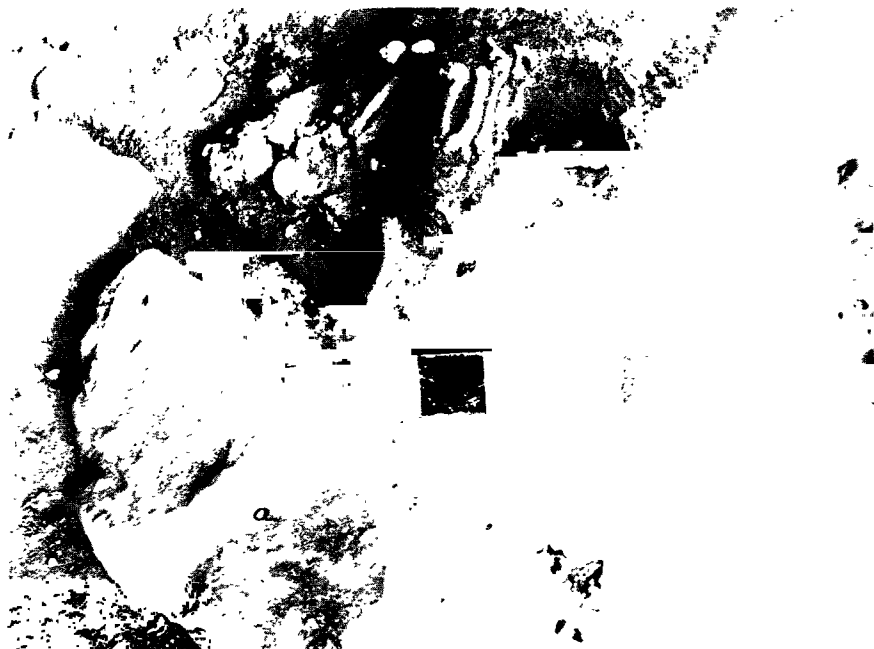
The skull of Shanidar I. *Upper:* As it was exposed in the laboratory at Shanidar. It represents a "classic" type Neanderthal, with a divided brow ridge like that of the Galilee Neanderthal skull. The top part of the Mousterian layer within which Shanidar I was found is dated at 46,000 years by the radiocarbon-14 method. *Lower:* The crushed condition of the skull. The bones of the left side had been pushed in toward the base. The friable nature of the unmineralized bones is shown. A fragment of mammal bone is lodged against the right parietal. The skull was cleaned and conditioned for the journey to Baghdad.



The postcranial skeleton of Shanidar I. The skull (x) had been removed prior to the uncovering. The remains of the left leg were found displaced and scattered, as shown.



Shanidar I. *Left*: The crushed and broken upper part. The skull (x) had been removed previously. The left hand was across the chest. The rib cage was broken outward to the left side in this view (right side of the skeleton). The underdeveloped remnant of the right arm (a), which could not be identified in the field, is seen among the ribs. One of the two flints found with the skeleton is to the right (b). *Right*: The confused condition of the pelvic area. The left femur is missing from its articulation with the hip joint, and the ilium bone of the left hip is shown broken over a rib bone (a) at the left arm elbow. A mass of animal bones (b) was found in this quarter. The left patella (c) was found as seen in this view.



Shanidar I. *Upper:* The feet bones, separated from the legs by the stones (*a*). A bone (*b*) was field identified as the distal end of the left femur. *Lower:* The broken bones of the lower legs, showing the displaced positions of the left tibia and fibula. Also field identified were the pieces of the left femur (*a*, *b*), and the right patella (*c*).



The relative positions of Shanidar I, II, and III in Shanidar Cave. Shanidar II (arrow in opposite or west wall) was found at a depth of 7.25 m. from the surface, or 7.25 m. from "0" datum. The large rockfall is indicative of some of the massive rockfalls in Shanidar Cave.



Lifting the cast containing the postcranial skeleton of Shanidar I from its resting place in Shanidar Cave. The feet had been removed in a separate cast, shown in the right foreground. The main shaft of the excavation is to the right of the author (right rear). Also helping in the lift is Tariq Mutwalli (left foreground), the representative of the Directorate General of Antiquities of Iraq. Shanidar II has also been prepared for removal.



The smashed skull of Shanidar II in the Mousterian deposits of the west wall of Shanidar Cave. The heavy brow ridges and the deep eye sockets may be distinguished in this full-face view. The lower jaw was broken over a stone as shown. The stone (*a*) to the left of the skull was found resting on the cranium.



The smashed and disarranged trunk bones (incomplete) of Shanidar III, found in the east wall of the excavation at a depth of 5.0 m. from the surface, or 5.4 m. from "0" datum. The position of the skeletal remains indicates that the man had been lying on his right side at an angle. The jumbled mixture of soil, stones, and bones is evident in this view, the result of a rockfall which must have killed Shanidar III.



The hearths, one above the other (*a*), contorted out of shape by the rockfall which killed Shanidar III (*b*), who lay in the same level. The remains of Shanidar III were badly broken and smashed by the rockfall.

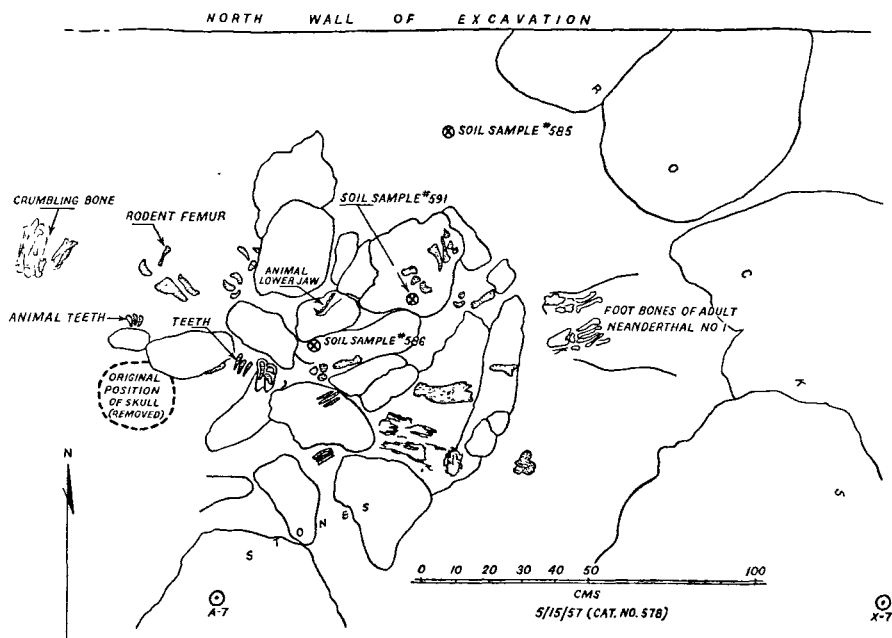


FIGURE 6.—Locations of animal bones found on and among the stones lying over Shanidar I.

had been crushed upon underlying stones of small size. Other bones were obviously displaced, and some could not be located. From the breakages and displacement of the bones, it appeared that the direction and thrust of the rockfall had been downward to the north and west. Of course, some shifting of the stones after the rockfall could have taken place.

When fully uncovered, the skeleton was found to be extended full length on its back in an east-west direction (pl. 5 and fig. 7). Approximating the position of the skull, which had already been removed, the length of the skeleton from head to feet was about 160 cm.³

The width across the shoulders was about 38 cm., and the distance from the neck to the hips, about 40 cm. The force of the stone fall seems to have been greatest on the individual's lower legs, his left hip, and the upper part of his chest. The feet, which lay higher than the rest of the body, had been cut off at the ankles and jugged outside the heap of loose stones in a relatively stone-free area.

In the upper part of the postcranial skeleton (pl. 6, left) it was noted that the left shoulder was higher than the right. The left collar bone or clavicle was in approximately normal position; the left shoulder bone or scapula was broken. The right scapula and

³ Using bone lengths, Dr. Stewart (1959, p. 277) estimates by modern standards a stature for Shanidar I of 5 feet 7 to 8 inches.

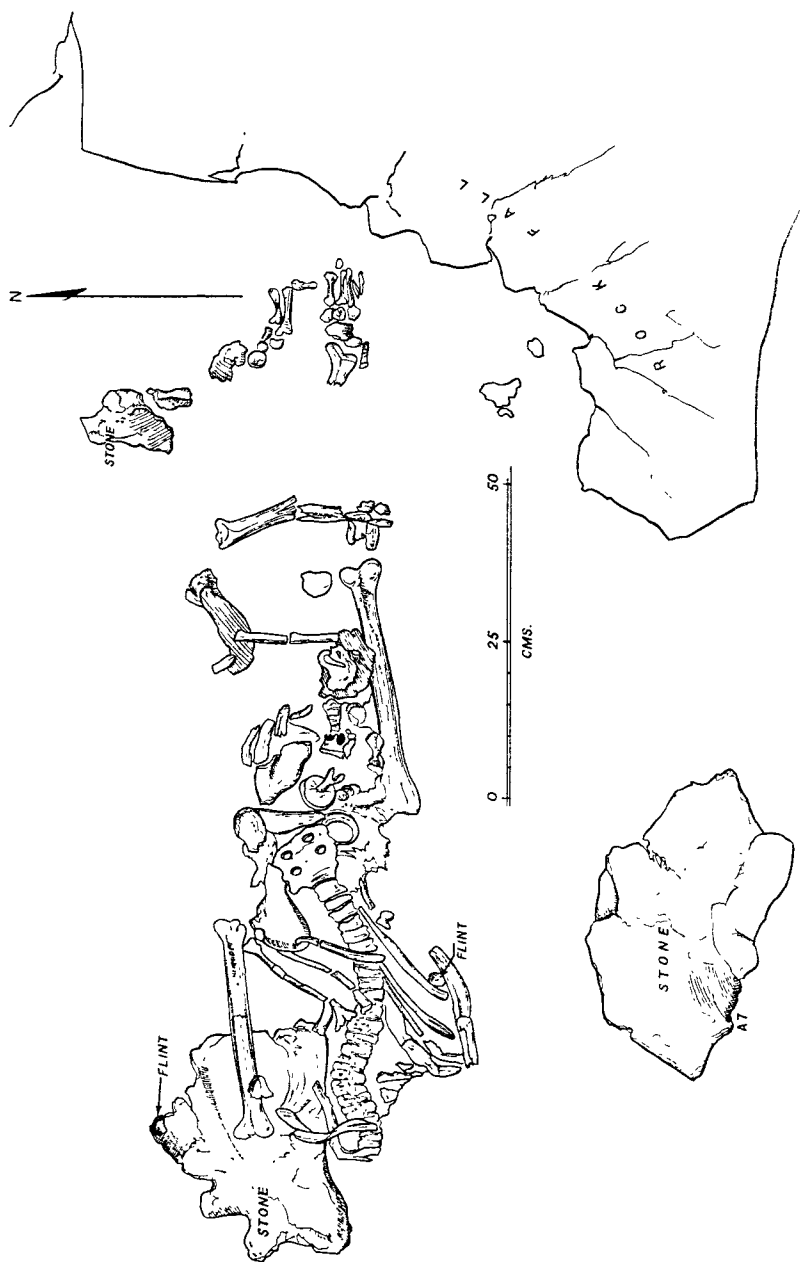


FIGURE 7.—The postcranial skeleton of Shanidar adult Neanderthal I.

right clavicle could not be identified under field conditions. There appeared to be a first rib arched under the left clavicle. A large, flat, limestone slab lay under the left shoulder and upper left arm. About 5 cm. of earth lay between the skeleton and the stone. The right upper arm was not recognized in the field. Later, in Baghdad, Dr. Stewart discovered (1959, pp. 277-278) that Shanidar I had an underdeveloped right scapula, clavicle, and humerus. He believes that this cripple's useless right arm had been amputated in life just above the elbow. This discovery accounts for part of our difficulty in identifying this part of the skeleton. Furthermore, the surviving parts of the right arm and shoulder had been caught underneath the right side of the rib cage. In contrast, the left arm lay with the elbow close to the body, with the forearm across the chest. The proximal end of the left humerus was shattered, and its midshaft was crushed under a stone. The bones of the left forearm, the radius and ulna, were somewhat separate and broken under stones. The vertebrae of the thoracic region were displaced to the right side. The ribs also were displaced to the right side, broken, split, and crushed.

The hip bones had suffered greatly in the rockfall (pl. 6, right). There were several double-fist-sized angular limestone fragments and two larger stones in this area. Adding to the confusion in this region was a loose scapula and about 16 other loose bones provisionally identified as of mammal origin. The ilium of the left hip was displaced headward at an acute angle and fractured over a left rib bone. I noted that there appeared to be a broad sciatic notch in the pelvis, generally considered a female trait among modern races, but Dr. Stewart has judged the sex to be male.

At and below the right hip joint was a heavy concentration of broken mammal bones and small stones, among which a bone provisionally identified as the left patella or knee cap was found. The shaft of the right femur was broken and crushed, but still in place, with the right patella at the inner side of the distal end of this bone. The left femur was missing from its place.

Five stones were removed from the area of the lower legs. The left tibia lay dislocated, over and at right angles to the axis of the right tibia, both bones crushed together under a stone 33 cm. long (pl. 7, upper). Fragments of the bones were found adhering to the underside of this stone. The proximal end of the left tibia lay over the proximal end of the right tibia (pl. 7, lower). The left fibula, also much displaced from its joint with the left foot, lay about 17 cm. to the west side of its normal position next to its companion bone. The stone had sheared across the distal shaft of the right tibia, leaving the broken joint end still in articulation with the right foot.

Although compressed, the feet had not been smashed, presumably because of the cushioning effect of the soil and the fact that heavy

stones did not actually strike them. The feet were about 15 to 20 cm. above the level of the rest of the body, close together, with the toes extended and pointing downward. The right foot, which lay slightly higher and more forward than the left, was exposed first. The heel of the left foot had been displaced to the north side, presumably by the stone which had torn away the left leg. The distal ends of the right tibia and fibula, cleanly broken, were found in articulation with the bones of the right foot.

About 23 cm. south of the right foot was found the knob end of a large bone, provisionally identified as the distal end of the missing left femur. About 10 cm. to the northwest of the left foot was found a section of the shaft of a large bone, which could not be positively identified, but may also have been part of the missing left femur.

My reconstruction of this fatal accident is that the individual had been killed by a rockfall while standing on the sloping cave floor facing the east. The fall of stones which struck him was a minor wave of a larger ceiling collapse toward the front of the cave. His body was not completely covered with stones, although the impact was forceful. Fortunately also for the preservation of the remains, the soil absorbed some of the blow. Had the stones been of tremendous weight, or if he had been caught against a solid bed of stones, his remains would have been crushed into an unrecognizable pulpy layer.

A number of stones must have fallen on him within split seconds, throwing his body backward full length down the slight slope. Presumably the first stones struck him on the head and across the feet and legs. The latter members were close together, with the left leg slightly flexed toward the right. The feet were caught fast under debris, while the lower legs were struck by two stones. One of these ripped the lower left leg from its foot, twisting the leg on its axis and turning it at a right angle to its opposite member. Simultaneously the other stone sheared off the lower right leg against another stone like a butcher's cleaver, crushing the upper part of the lower left leg against it. Some of the force of the blow must have been to the northwest as well as downward. His left upper leg must have been smashed by a very heavy impact, since the left pelvic bone was forced headward over the lower ribs and the left femur was displaced. Possibly the section of large bone found a few centimeters to the north of the ankles, and another broken bone found to the south of the feet, are pieces of the left femur.

In falling backward, his body twisted to the right, pinning down his useless stump of a right arm. His left arm and hand, drawn protectively to his chest, were crushed into his ribs and spine. At the same time, his lower thoracic vertebrae were thrust to the right.

His head and neck were severed from the trunk and left in an unnatural attitude. His head faced over his right shoulder, at a right

angle to his chest. The lower jaw was dislocated to the front and left side of the cranium and broken against a flat stone.

The many broken and split mammal bones over and around and in direct contact with the skeleton have been mentioned. Two especially thick concentrations are noteworthy: one directly over and slightly to the east of the pelvic area, and another over the left shoulder and left upper arm. These masses of bones could have been rodent nests. The eccentric position of some of the individual's bones and the apparent absence of others might be laid to rodents. Thus, animal action was very likely responsible for the strange displacement of the left fibula and for the absence of the left femur from its normal position. The shifting of soils and stones could not have produced this effect.

I believe that survivors of the rockfall returned after a while, and seeing what had happened, heaped some loose stones, the closest at hand, over the unfortunate's remains. Some of the loose mammal bones lying on top of and among these stones may have been part of a funeral feast. Some of the mammal bones crushed under the stones were certainly not the result of rodent action. Eventually a few centimeters of occupational deposit accumulated over the heap, followed by another rockfall, which sealed off the Mousterian deposit in this quarter. Thus ended a people and an age at Shanidar Cave.

Although he was born into a savage and brutal environment, Shanidar I provides proof that his people did not lack in compassion. Here was an armless cripple, a *pre-sapiens* individual, who could barely forage and fend for himself. We must assume that he was accepted in his society and supported by his companions throughout his lifetime. That he made himself useful around the hearth is evidenced by the unusual wear on his front teeth. It indicates presumably that in lieu of a right arm he used his jaws for grasping. The stone heap over his remains shows that even in death his person was an object of some esteem, if not respect, born out of close relationship against a hostile environment.

Two flints were found close to the skeleton (pl. 6, left; fig. 7), but these were not necessarily part of Shanidar I's tool kit. One was an oblong gray chert flake measuring 3.3 cm. long, 3.1 cm. wide, and 0.3 cm. thick. It has a beveled edge on one long side showing use retouch. This specimen was found 15 cm. to the north of, and slightly lower than, the left shoulder. On the opposite side of the skeleton, touching the inner side of the ribs, was another flint. It was a black flint flake showing no retouch.

As the skeleton was exhumed and cleaned of earth, the bones were coated with a solution of Nicol cement (pl. 8). Since our field observations on the remains *in situ* could never be as thorough as under controlled conditions in the laboratory, it was thought that the entire

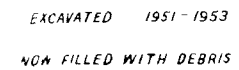
skeleton should be removed *en bloc*. Each separate bone could then receive the attention it required, and the whole skeleton could be studied at leisure. Therefore, I determined that we should encase the skeleton as it lay. Since the feet and adjacent parts appeared to form a reasonable unit, I decided to make them a separate package. The body proper, including the lower limbs, made another unit of manageable size. On May 30, after the bones had been thoroughly coated with a protective film, we packed a sheathing of cotton and waste over the bones. Over this we put successive strips of burlap cloth soaked in plaster of paris. For rigidity and strength, a frame of wood and lath was put over and around the skeleton. After the top of the skeleton was covered sufficiently, we undercut the remains, adding successive strips underneath. A number of stones were encountered below the remains and had to be included in our casing. In this manner, the body of the skeleton was encased in one block, and the feet in another. The removal of the feet was a simple matter; that of the larger casing was quite another, necessitating the combined strength of seven men to raise it to the top of the excavation (pl. 9).

The following day, May 31, a team of eight men was organized to carry the larger cast down the trail. A four-poled rig of tree limbs was formed into a sort of suspension carriage, two poles on either side of the cast. A man was positioned at the end of each of the poles. It looked like the prototype of a knee-action vehicle. The men had gone no more than 50 yards when it became obvious that more manpower was needed. I had to send out into the fields to impress five more men into service. The portage went easier with the larger crew.

The casings were boxed that night, and on June 1, at 5:30 a.m., left Shanidar police post by truck for the railroad station at Erbil, accompanied by an armed escort of three policemen riding high on the box.

SHANIDAR II

The discovery of Shanidar II (field cat. No. 619 III; pls. 8, 9, 10), on May 23, during the last week of the season at Shanidar, was almost overwhelming. I had ordered one of my ablest Kurdish workmen, Mohammed Amin, to clean the west wall of the excavation for diagraming. This was one of the last stages of our work before closing down the excavation for the season. Wall cleaning is done by peeling or scraping away thin sections in order to expose fresh surfaces for detailed observation and to facilitate distinguishing soil changes. In so doing, the workman's trowel exposed the edges of several teeth at a depth of 7.25 m. from "0" datum in square D 8 of Layer D (figs. 1, 8, 9). The worker, being well trained, called me to the spot to make an examination. I could not decide immediately what he had discovered. The teeth were barely visible in the section, but appeared to


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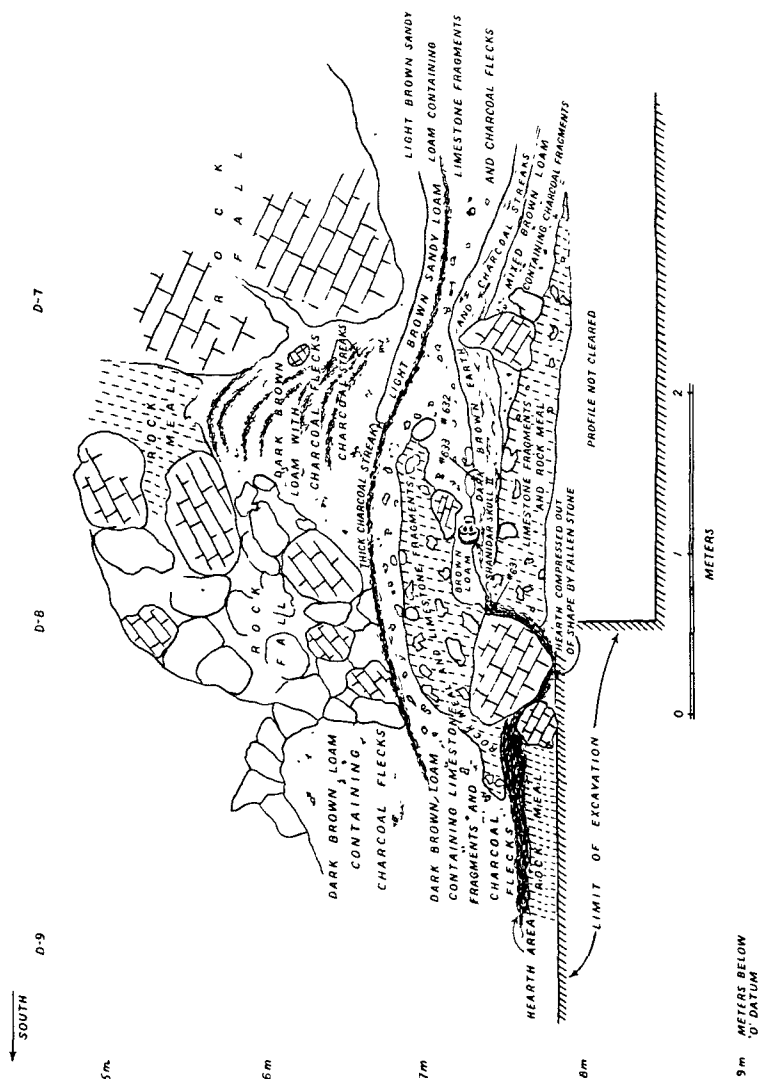


Figure 9.—Detail of cross section of west wall showing location of Shanidar II.

be fixed in a jaw. I thought it might be a pig, or some other mammal. Because at the time there were other pressing duties connected with the recovery of Shanidar I, I drew a large circle around the teeth, and stuck a surveying pin in the earth near them in order to mark the spot so that caution would be exercised in the vicinity. The worker was ordered to proceed with cleaning the wall until we were ready to explore the find further.

It was not until 2 days later, after the entire western wall had been cleaned for sectioning, that the fragmented skull of the second adult individual was exposed and recognized. The base of the skull lay at a depth of 7.4 m. from "0" datum, about 7 m. to the west and slightly to the south of Shanidar I. Judging from the evidence, this individual also had been killed in situ. He appeared to have been caught and crushed under a rockfall, which compressed his skull laterally and contorted his neck. There was a soft earth fill of 12 cm. between the top of the skull and the rockfall. The skull faced to the east, with the top of the head toward the south, and the lower jaw to the north. The skull was crushed over a limestone cobble measuring 8 by 12 cm. The lower jaw was broken, mouth agape, over the stone. The front of the skull was compressed to a thickness of between 5 and 6 cm. A limestone cobble about the size of two doubled fists was picked off the left temple, some fragments of bone adhering to it. The eye sockets, crushed out of shape by the stones, stared hollowly out from under a contorted heavy brow ridge. The latter was broken, the left side lapping over the right side. Owing to the force of the blow, the left parietal had overlapped the right parietal at about the midline of the skull. Behind the heavy torus was a slanting brow, which could be appreciated even in its shattered state. The nasal bones were broken, and the front part of the upper jaw was smashed. There was a good right maxilla.

Approximate measurements were taken with a wooden metric ruler. The distance from the center of the brow to the displaced chin measured about 28 cm. The skull was about 20 cm. long. The width of the lower jaw in its crushed state was about 5 cm. There was a definitely rearward slope to the chin region. The length of the lower jaw from the front to the ascending ramus was about 11 cm. The width of the ramus was about 4.5 cm.

The rear of the skull, lower than the front, rested on a bed of loose, soft, brown earth. Stones were visible behind the skull, extending into the wall. A series of vertebrae, which were exposed with difficulty in the limited space among the stones, had been contorted, arching upward to the rear at a very unnatural angle. The rest of the vertebrae and some isolated fragments of the post-cranial skeleton could be seen in the face of the excavation behind the skull.

Like the bones of Shanidar I, those of Shanidar II were fairly well preserved, although crushed. None was mineralized. This is characteristic of all the bone remains from Shanidar Cave (with the possible exception of the bones encased in the stalagmitic lenses). Actually they looked fairly fresh, but with some dark staining on the outer surfaces. The soil peeled away from them very easily. When fully exposed the configuration of the skull left little doubt that this was another Neanderthal find.

The stratigraphy in which the skull was found illustrated particularly well a succession of quiet occupational periods broken by large and small rockfalls. Shanidar II was found about 1.5 m. below the contact of layers C and D, and thus in the top part of the latter. The skull rested on a bed of dark-brown sandy loam measuring 20 cm. thick. This bed, contemporary with the skull, was streaked with charcoal. Thirty cm. to the south was the edge of a large, thick, widespread hearth between 5 and 20 cm. thick, which was compressed into a U-shape by a boulder. The same bed of dark occupational soil extended about 1.5 m. eastward in squares D 8 and D 9 where at the 7.2 to 7.5 m. level it was bounded by a large concentration of rockmeal and crushed stones. This occupational horizon yielded an abundance of charcoal flecks, mammal bone fragments, one bear(?) tooth, flint flakes, and two long Mousterian-type points of flint. At the same level in square D 9 was found a large boulder, presumably part of the rockfall that killed Shanidar II.

The Shanidar II occupational layer extended over a sterile bed of limestone fragments and rockmeal, undoubtedly due to an earlier rockfall. This rockfall sloped from east to west, conforming to the general slope of the cave deposits, and measured 30 cm. thick beneath the skull. It appeared as an intrusive layer in an occupational horizon, to the north overlapping some stones and a lens of brown sandy soil.

The rockfall that killed Shanidar II was the forerunner of a larger fall of rocks, the main force of which came to within about 25 cm. of the skull. However, since a full exhumation of the postcranial skeleton was not made, the possibility cannot be ruled out that the skull was caught on an uneven rock surface. In any case, the situation was fortunate, because if the skull had received the full brunt of the rockfall, it would have been destroyed. The loose brown soil, containing charcoal flecks, found between the skull and the heavy rocks above, conceivably could have filtered in from the sides through cracks and crevices in the stones.

Following this rockfall, the cave was reoccupied in this quarter, as evidenced by a superposed occupational horizon. A circular hearth was found at a depth of 7.05 m. in the center of square D 8. It measured 20 by 25 cm. and was 10 cm. thick. Mammal bone fragments,

flint flakes and Mousterian-type artifacts also were found at this depth. Indeed the first specimen recognized in this section as indicative of the Mousterian layer was a Mousterian-type point from the 5.75–6.00 m. level in square D 9.

The top of layer D in this area was sealed by an exceptionally heavy rockfall, which bent a long, widespread lens of charcoal-stained soil at a depth of about 6.8 m. Charcoal streaks, excellent indicators of soil disturbance, were markedly compressed and bowed downward by the same rockfall between 5.5 and 6.5 cm. The top of this rockfall lay at a depth of about 4.5 to 5.0 m. These data prove that Shanidar II was found well within the Mousterian layer.

Removal of the skull presented a fairly simple problem. An excavation of about 60 cm. long by 25 cm. wide and 40 cm. deep exposed the skull fully. The soil was removed to the region of the clavicle. Because the skull was in such close quarters, and part of it adhered to a stone, it had to be taken out in two sections. The front part formed the first cast, and the rear or occipital part formed the second cast. The limestone rock upon which the skull rested had to be included in the first cast. The protected remains were carried down the mountain trail on June 1, using the same means by which the Shanidar I skull was transported.

The postcranial skeleton, unfortunately, had to be left in the cave deposit for another season. I estimated that it will take at least two months to exhume it properly, digging down from the top, a time-consuming operation. Before we closed our work in the cave, a wall of stones was placed across the front of the area where Shanidar II was found to insure the safety of the remaining bones.

SHANIDAR III

Discovery of Shanidar III (field cat. No. 384 III; pls. 1, 11, 12; fig. 10), on April 16, antedated that of Shanidar I and II, but under field conditions its identity was not confirmed until later. It was the order of recognition of the finds, therefore, and not that of discovery, which determined the numbering. Indeed, the Shanidar III find had not even been entered in the early preliminary statements written in the field (Solecki, 1957b, c).

The remains consisted of some parts of the trunk and lower limbs and several teeth of an adult skeleton. As in the case with Shanidar I and II, this find was made in the course of cleaning and straightening the profile of the excavation. Shanidar III was found in the east wall of the excavation at a depth of 5.4 m. below "0" datum (fig. 3), in the extreme northeast corner of square B 9, or practically at the junction of squares A 8, A 9, B 8, and B 9 (fig. 1). It was about 2.75 m. south of, 0.5 m. west of, and 70 cm. below Shanidar I.

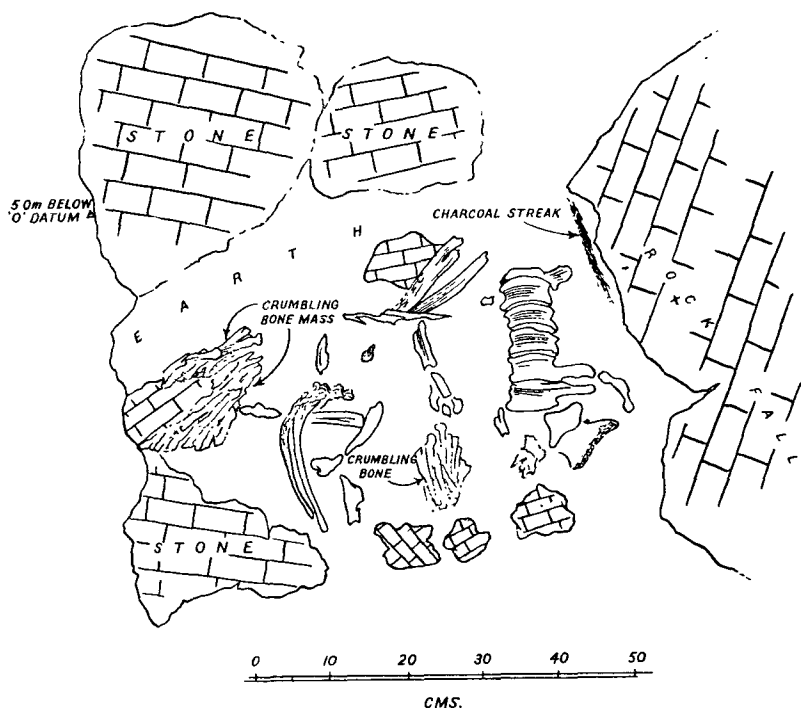


FIGURE 10.—Skeletal remains of trunk of Shanidar III.

The first signs of the skeletal remains occurred when one of the workmen called my attention to some unrecognizable crushed and fragmented bones. They were lying at an oblique upward angle in a churned mass of yellow loamy soil and limestone blocks (pl. 11). These fragments looked like the foot and leg bones of some large mammal and I judged that it had been killed in a rockfall. The bones appeared to be in articulation, and definitely were not the usual cracked and broken assortment of miscellaneous mammal bones encountered in occupational levels. Among these bones one fragment was later identified as the distal end of a human fibula.

The bones were found intermingled among sharp angular fragments of limestone in a 30 cm. thickness of yellow loamy soil, part of a poor occupational horizon which had been twisted and contorted out of shape by a relatively light rockfall. Some powdery gray rockmeal, a large share of which must have come from crushed stones, was also found in the composition. One meter to the south of the find in a similar pocket of earth, joined by a warped section of the deposit, were found two small hearths, one above the other (pl. 12). The hearths lay 10 cm. above the level of the bones. Both hearths measured about 70 cm. in diameter and 5 cm. in thickness. They had been

warped downward at the ends by the terrific pressure of fallen stone blocks. Shanidar III was probably contemporary with the uppermost of the two hearths.

Our two Shergati assistants were detailed to clean the soil from around the skeletal remains during the next few days, exposing the remains of the trunk, which lay behind the shattered limb bones. The trunk was represented by five lumbar vertebrae in articulation, some scattered and broken ribs, and parts of the pelvis and sacrum. Rib fragments were collected 35 cm. away from the vertebral column. Two areas of crumbled bone, one measuring 20 by 10 cm. and the other 12 by 7 cm., were observed under stones in the same plane as the trunk. All the bones were scattered in an area 65 cm. broad by 35 cm. deep. They lay in a soil pocket measuring 70 cm. by 55 cm. among limestone blocks at the base or western edge of a rockfall. Unfortunately for field identification and recovery, much of this osseous material had been reduced to compacted masses of powder adhering to the limestone fragments and blocks. None of the recoverable bones was mineralized, and each could be separated very easily from the soil. Also none of the bones appeared to have been molested by animals, or at least none of the bones showed evidence of gnawing or chewing. However, it is possible that animals may have removed some of the bones of the cephalic end. The several teeth which were recovered had passed unnoticed into collecting bags during preliminary investigations in this section and were not retrieved until a comparative examination of the remains was made. The teeth seemed to have been scattered in the vicinity of the bones.

From the evidence, it appears that Shanidar III had been accidentally caught, like Shanidar I and II, under a rockfall and instantly killed. Death was not due to either of the rockfalls that caused the deaths of the others. Unlike the others, and unfortunately for us, this body seems to have been jammed into a crevice among the stones, and the upper parts, including the head and arms, had been sheared away. No part of the skeleton above the lumbar vertebrae was found in place. It appears as though the trunk had been in an upright position when it was caught by the rockfall. The legs were flexed close to the trunk. From the angle of the trunk and of the several parts of the lower limbs, the individual had been lying on its right side, its upper extremities directed obliquely to the east, and its lower extremities to the west.

We could not immediately resolve the identity of the remains, although they looked suspiciously humanlike. Photographs were taken of the remains in situ and a drawing of the same was made for the record. The bones were picked out by our Arab technicians after a preservative coating was applied to the exposed surfaces. They

were then packed in a large wooden box filled with cotton, and not touched again at the laboratory at Shanidar or unpacked for reexamination in Baghdad. It was not until the remains were examined and compared at the U.S. National Museum in Washington that the true nature of Shanidar III was disclosed.

Speaking at a lecture in the Smithsonian Institution on February 27, 1959, Dr. Stewart revealed that Shanidar III, probably a male, had had a blade stuck between two of his ribs. Evidence showed that there had been some healing of the bone. Presumably Shanidar III had been disabled in a conflict with unfriendly neighbors and was recuperating when he was killed by a rockfall.

Judging from stratigraphic position, it appears that Shanidar III lay in a relatively thin occupational stratum which was further compressed, like a sandwich filling, between two stone layers. In the vicinity of the neighboring hearths mentioned above, the stratum measured 45 cm. thick. In the vicinity of the skeletal remains, the stratum measured about 30 cm. thick. There is a striking similarity between the situation of Shanidar III and Shanidar I, less than 3 m. away. Both skeletons were found in shallow occupational deposits between two rockfalls. However, the two could not be contemporary, since the occupational layer of Shanidar I, as well as the 40 cm.-thick rockfall which covered Shanidar III, separated them stratigraphically. The difference in position probably represents in years less than a millennium.

The Shanidar III occupational layer dipped markedly toward the west. The soil was a light-brown loam, containing flecks of charcoal, mammal bone fragments, flint flakes and several artifacts. The latter included a Mousterian point, a thick "circular" scraper and a discoid core flake. At about the 5.0-m. depth was much evidence of a rockfall, the one which killed Shanidar III. At about a depth of 4.5 m. was found an occupational deposit which seems to have been an extension of the Shanidar I layer. One broken Mousterian point and other Mousterian-type artifacts were found in this horizon. This marked the top of the layer containing Mousterian remains in this quarter. Overlying it was found a rockfall probably representing the same one which killed Shanidar I. The first signs of the Baradostian culture above Shanidar III appeared at a depth of 4.25 m.

THE ROCKFALLS IN SHANIDAR CAVE AND THE COMPARATIVE STRATIGRAPHY

Translated from mute stones and earth, the stratigraphy in which the skeletal remains were found reveals a succession of occupations which were from time to time shattered by large or small rockfalls.

The dangers of the caveman's life were by no means shut out when he crossed the portal to his airy cave home. He never knew when a falling stone would come crashing down. But it evidently did not worry the Neanderthals any more than it does the Kurds at Shanidar Cave today. Shanidar Cave lies in an earthquake belt, and earthquakes undoubtedly triggered the repeated rockfalls. Actually a geological fault passes in front of the cave.

At least four major rockfall series could be identified in the excavation: One at 9 m. depth, a second at 6 m., a third at 4 m., and a fourth (and possible fifth) near the top. The minor rockfalls probably numbered over a score. Some estimation could be made of the sequence and contemporaneity of rockfalls by tracing the deposits in which they lay. None of the rockfalls, not even the severest, blanketed the entire floor of the cave so far as could be observed, nor were the rockfalls of regular thicknesses. Their distribution depended on natural structural weaknesses in the limestone cave ceiling. The spread of large stones on the modern surface of the cave floor attests the fact that the rockfalls have not ceased. I can attest, too, that I experienced an earth tremor while at work in the cave during the summer of 1953. Happily, no rockfalls accompanied this quake.

The Stone Age dwellers of Shanidar Cave, like the modern Kurdish occupants, naturally lived around the rock areas and among them. Their household debris and the accumulating soil gradually filled in the areas among the stones, leveling the rough parts of the cave floor until another ceiling collapse started the whole process all over again. It is highly unlikely that a large group of Shanidar people were killed in the cave at one time. The cave deposits show that reoccupation began shortly after each rockfall, at least up to about the time of Shanidar I Mousterian times.

When the skeletons were brought to Baghdad and were awaiting disposition in June 1957, I pointed out to Dr. Naji al Asil, then Director General of the Directorate General of Antiquities, that the expedition's sponsor, the Smithsonian Institution, had a qualified physical anthropologist, Dr. T. D. Stewart, who could make a study of the remains. The suggestion was accepted, and telegrams were dispatched to the Smithsonian Institution, inviting Dr. Stewart to come to Baghdad. Unfortunately, he was not able to arrive until October 1957, after the skeletons of Shanidar I and II had been dismembered by the laboratory technicians in the Iraq Museum. As mentioned above, Shanidar III had been shipped to Washington.

The material, including the artifacts, recovered from Shanidar Cave have not yet been fully studied. Studies of soil and pollen

samples, and of the mollusks and other faunal remains have either been completed or are in various stages of completion.⁴

THE DATING OF THE SHANIDAR NEANDERTHALS

We have reached the stage, thanks to the carbon-14 dating method, where we may estimate with something approaching certainty the age of the Neanderthals of Shanidar Cave. The base of the Baradostian (Layer C) appears from a series of dated carbon-14 samples to be close to 35,000 years old.⁵ There seems to be a cultural hiatus between this level and the top of the Mousterian (Solecki, microfilm), which is now confirmed by unpublished carbon-14 dates obtained by Dr. H. de Vries of Rijks University, Groningen, the Netherlands. In a letter dated May 25, 1959, Dr. de Vries allowed me to quote a carbon-14 sample dated as $50,000 \pm 3,000$ –4,000 years before the present (GRO 1495). This sample was taken from an area about 6 m. from Shanidar I. Taking the slope of the deposits into account, and barring any accidents in stratigraphy, I concluded in a recent paper (Solecki, 1959b, p. 714), that this carbon-14 date was probably closer to the actual date of Shanidar I than my estimated date of 45,000 years (Solecki, 1957c, p. 63; 1957d, p. 28; 1958, p. 106; 1959a, p. 406). The latter estimate was a relative dating based on comparative studies. In a more recent letter (August 1, 1959), Dr. de Vries permits me to quote two more carbon-14 dates from Shanidar Cave. One is from the base of Layer C, with a date of $35,080 \pm 500$ years B.P. (GRO 2549). The second, which is of more pertinent interest, was a carbon-14 sample dated $46,000 \pm 1500$ years B.P. (GRO 2527). This sample was taken from an occupational layer about 50 or 60 cm. below the contact of Layers C and D in the top of Layer D, at a depth of 5.10 m. below "0" datum. It was taken from a spot about 4.5 m. from Shanidar I, and about 3 m. from Shanidar III. From its stratigraphical position, the sample appears to date the cultural sublayer of Shanidar I. Therefore, unless proved otherwise in the future, I consider that the Shanidar I Neanderthal is about 46,000 years old, and Shanidar III perhaps a few hundred years older by virtue of its slightly lower stratigraphic position. The latter was separated vertically from the former by a thin mantle of stones and occupational deposit both totaling about 70 cm.

* The soils have been examined for pollen by Dr. Gunnar Erdtman of the University of Stockholm, Madame Arlette Lerol-Gourhan of the University of Paris, and Richard Shutler of the Nevada State Museum. Madame Lerol-Gourhan promises exceptional results with her methods. The Soil Conservation Service of the U.S. Department of Agriculture examined the physical nature of the soils. Dr. Harald Rehder and Dr. Alexander Wetmore, both of the U.S. National Museum, each in his own respective specialty, examined the mollusks and bird bones. Dr. Charles Reed of the University of Illinois is studying the mammal bones.

⁵ The series of carbon-14 dates from Shanidar will be published in collected form.

In earlier papers (Solecki, 1957c, p. 63; 1959b, p. 715), I estimated an age of about 60,000 years for Shanidar II. This estimate was based on an interpolation between the carbon-14 dates for the lower part of Layer C, and the probable identification of a stalagmitic horizon with a pluvial period, or Würm I in the Alpine sequence. As charted by Emiliani (1956, fig. 1; 1958), the Würm I stage is dated as about 65,000 years. The stalagmitic horizon (actually, several closely spaced sheaves of discontinuous stalagmitic lenses clustered around one widespread layer) lies at a depth of 8.5 m. Reasoning that with a carbon-14 date of 50,000 years for a level at a depth of 5.0 m. in the western part of the excavation, it seems very likely that Shanidar II (depth 7.25 m.) is closer in age to that of the stalagmitic horizon. This would place the age of Shanidar II at about 60,000 years, assuming of course that the stalagmitic horizon may be equated with Würm I, and that Emiliani's calculations are correct for his estimate of the age of Würm I.

It is possible that with advanced technology in the carbon-14 method or some other method, a more closely approximate date for Shanidar II will be obtained in the future. However, until this is done, the approximate age of 60,000 years is given here.

The Shanidar infant, found a short distance above the main stalagmitic layer (Solecki, 1955a, p. 417; 1955b, p. 30), must be older than Shanidar I, II, and III, and younger than the stalagmitic layer. As indicated above, I believe this layer represents a pluvial period of Würm I age. I estimated an age of 70,000 years for the Shanidar infant in an earlier paper (Solecki, 1957c, p. 63), based on then current age approximations of Würm I. With Emiliani's new estimate of Würm I as about 65,000 years old, we might revise our figure accordingly to about 64,000 years(?). Again, this is a provisional approximation, which we offer until a more accurate appraisal of the geology can be made at Shanidar Cave. Madame Arlette Leroi-Gourhan's analysis of fossil pollen from this horizon in Shanidar Cave should furnish us with more definite information on climate in the near future.

Dr. Muzaffer Şenyürek, of Ankara University, who studied the Shanidar infant, believes it to be a baby girl (Şenyürek, 1959, p. 10). He thinks that it represents a new "subspecies" of Neanderthal, closely related to the ancestors of *Homo sapiens*. He proposes to name it as a new form of Neanderthal man, "*Homo sapiens shanidarensis*" (Şenyürek, 1959, p. 125). It will be interesting to see what the findings of Dr. Stewart on the adult Neanderthals will reveal with respect to this classification of the Shanidar infant.

PROVISIONAL RELATIONSHIPS OF THE SHANIDAR NEANDERTHALS TO
NEAR EASTERN COUNTERPARTS

Eight cave and rock-shelter sites in southwest Asia, not including the Soviet finds, have yielded remains of Neanderthal man. Howell (1958, p. 185) enumerates seven of these: M. ez-Zuttiyeh, the caves of Mount Carmel (M. et-Tabūn and M. es-Skhūl), Shukbah, Djebel Qafzeh, Bisitun, and Shanidar. It is noteworthy that of these sites, five are in Palestine, the most intensively investigated region. Bisitun (Coon, 1951) is a cave site in western Iran. I hesitate to include Bisitun in this list, since a positive validation of the skeletal remains from this site has never been made to my knowledge. I assume that Howell follows Coon's (1951, p. 79) tentative identification. Deserving of recognition as an eighth site of this sort is Karain Cave near Antalya, Turkey, where two Neanderthal teeth were reportedly discovered (Kökten, 1949; Şenyürek, 1949).

Of all these sites, Mount Carmel (Garrod and Bate, 1937; McCown and Keith, 1939) presents the best material yet found and published in the Near East for comparison with the Shanidar adult Neanderthals. However, the situation at Mount Carmel is somewhat complex. Neanderthals of the primitive or "conservative" type, represented by the Tabūn skeletons, and of the more advanced or "progressive" type, represented by the Skhūl skeletons, were recovered. Contesting the original dating of the skeletons to the Riss-Würm interglacial period in the Alpine sequence, Vaufray (1939-1940, pp. 616, 619) and Bordes (1955, pp. 504-505) assign the Mount Carmel skeletons to later dates: Würm I-II interstadial and Würm III, respectively (Garrod, 1956, p. 50). Garrod (1956, pp. 56, 58-59) notes new evidence to support the possibility that the layer at Mount Carmel yielding fossil skeletons (Lower Levalloiso-Mousterian) dates from the early stages of Würm I. Here Howell (1958, p. 188; 1959, p. 9) agrees that the skeletons date from Würm I. Unfortunately, at this writing, no carbon-14 dates are available to give us a confirmation of this view. However, Dr. John d'A. Waechter of the University of London Institute of Archaeology undertook a special mission to Mount Carmel during the summer of 1959 to recover carbon-14 samples. Pending the results of his investigations, carbon-14 dates from elsewhere in the Near East and North Africa tend to support Dr. Garrod's relative dating. According to a letter from her dated October 10, 1959, there is additional evidence both from the dating of Levalloiso-Mousterian sites by carbon-14 dates, and from beach terraces, lending additional weight in her favor.

Dr. Garrod's relative dating of the Mount Carmel Lower Levalloiso-Mousterian layers and the associated skeletons as of early Würm I age is close to our more precise dating of the Shanidar adult skele-

tons. Following Emiliani (1956, 1958), the latter date from the final part of Würm I and probably well into the Würm I-II interstadial, on the basis of the carbon-14 measurements. This would make the Shanidar skeletons somewhat younger than the Mount Carmel skeletons. We have additional evidence to offer on the basis of comparative stone typology, albeit not detailed at this writing, supporting this conclusion. Thus, Garrod (in Garrod and Bate, 1937, p. 119) commented that the stone industry of the Upper Levalloiso-Mousterian of Mount Carmel closely matched the Mousterian industry of Hazer Merd caves in northern Iraq near Sulaimaniya, sites which Garrod (1930) had excavated. With the exception of several implement types which were absent at Shanidar, the Mousterian industry of Shanidar appears to be similar to that of Hazer Merd, as well as to that of Bisitun (Solecki, 1955a, pp. 419-420; microfilm 1958, pp. 26-27). Garrod (1956, p. 57) has corroborated the similarity of these Mousterian industries. I have been able to compare directly a sample collection of the Mousterian industry from Shanidar with the sequence of stone industries from Mount Carmel as represented in a collection in the U.S. National Museum. I found that with the apparent exception of Levallois cores, hand axes, and burins, which were absent at Shanidar, the Upper Levalloiso-Mousterian of Mount Carmel is most like the Shanidar Mousterian industry. The Mount Carmel Lower Levalloiso-Mousterian, with its associated Neanderthal skeletons, must then perforce be earlier than the Shanidar Mousterian on considerations of the stone typology.

With regard to human paleontology, there are unmistakably more points of resemblance between the Shanidar I (Stewart, 1958, p. 91; 1959, p. 277), and Shanidar II skulls and the "conservative" Tabūn cranial remains than the Skhūl remains. In addition to these resemblances, Dr. Stewart (unpublished statements) found evidence in the remains of Shanidar III which show that it is closer to the Tabūn than to the Skhūl skeletons. This makes a strong argument for equating the adult Shanidar population with the conservative Tabūn remains. However, if on the basis of relative dating and stone typology we accept the inference that the Mount Carmel Neanderthals are older than the Shanidar adult Neanderthals, we would have to accept the proposition that a population of Neanderthals with Tabūn characteristics lived on in the Zagros Mountains some thousands of years after their physical counterparts in Palestine. Reflecting upon the long timespans of man and culture in the Old Stone age, this need not be a startling thought. The Mousterian period, the time of the Neanderthals, has been given a span of at least 45,000 years (Emiliani, 1956, table 1). The enigmatic Skhūl Neanderthals with modern-man characteristics are another matter. Howell (1958, pp. 186, 189-191) notes that they may be somewhat

later than the Tabūn finds, though still within the Lower Levallois-Mousterian. Unfortunately, for comparative reasons, except for some isolated skeletal fragments from Tabūn, no skeletons were found in the Upper Levallois-Mousterian at Mount Carmel. However, even these remains may be highly useful to compare with the Shanidar Neanderthals.

Elsewhere in Palestine, the site of Shukbah (Garrod and Bate, 1942; Keith, 1931) has yielded isolated skeletal fragments found with direct Upper Levallois-Mousterian cultural associations. These remains may be of prime importance for the Shanidar study, since they should be approximately in the same time horizon and cultural level. One other site, Mugharet el-Zuttiyeh (or M. ez-Zuttiyeh of Howell, 1958, p. 185), yielded the very interesting Galilee skull (Turville-Petre, 1927). The Galilee skull, although from a lower cultural horizon than Shanidar, or in the Lower Levallois-Mousterian, has some resemblances to Shanidar I. Particularly interesting, in my opinion, are the rather divided brow ridges on both specimens.

Presumably the terminal date for the Upper Levallois-Mousterian culture at Mount Carmel is about the same as the terminal date for the Mousterian elsewhere in the Near East. Thus, the date of 46,000 years for the top of the Mousterian layer at Shanidar is closely matched by the date of 43,000 years at Jerf Ajla in Syria (Coon, 1957, p. 315). It is hoped that we can soon reach back farther into the past with newer and more refined methods of dating. The "provisional" correlation tables are fast becoming outmoded, as new firm dates are added to the list.

CONCLUSION

Three adult Neanderthal skeletons, Shanidar I, II, and III, were recovered from the upper part of the Mousterian deposits of Shanidar Cave by the Third Shanidar Expedition in 1957. The youngest of these remains, Shanidar I, is dated at about 46,000 years ago. The others, by virtue of their lower stratigraphic positions, are somewhat older. The deposits in which the Shanidar Neanderthals have been found are correlated with the Upper Levallois-Mousterian of Palestine; hence they are younger than the well-known Lower Levallois-Mousterian Neanderthals of Mount Carmel, 600 miles away. The latter are now accepted as of early Würm I age in the Alpine sequence by Dr. D. A. E. Garrod.

The Shanidar remains should provide us with information about the final Neanderthal population in the Near East, and what happened to them during and after Würm I times in that part of the world. Significantly, the Shanidar population on first impression appears to be more closely related to the "conservative" Tabūn skeletons than to the "progressive" or more advanced Skhūl skeletons.

The gap of years between the Middle and the Upper Paleolithic deposits at Shanidar may be explained in terms of a return to the area of an extreme cold period. This presumably rendered the cave uninhabitable between circa 45,000 and 35,000 years ago, driving the Neanderthal populations away for all time.

When the exploration of Shanidar Cave is finished, we may expect to have still other links in our understanding of the Paleolithic period in the Near East, its times, and its people.

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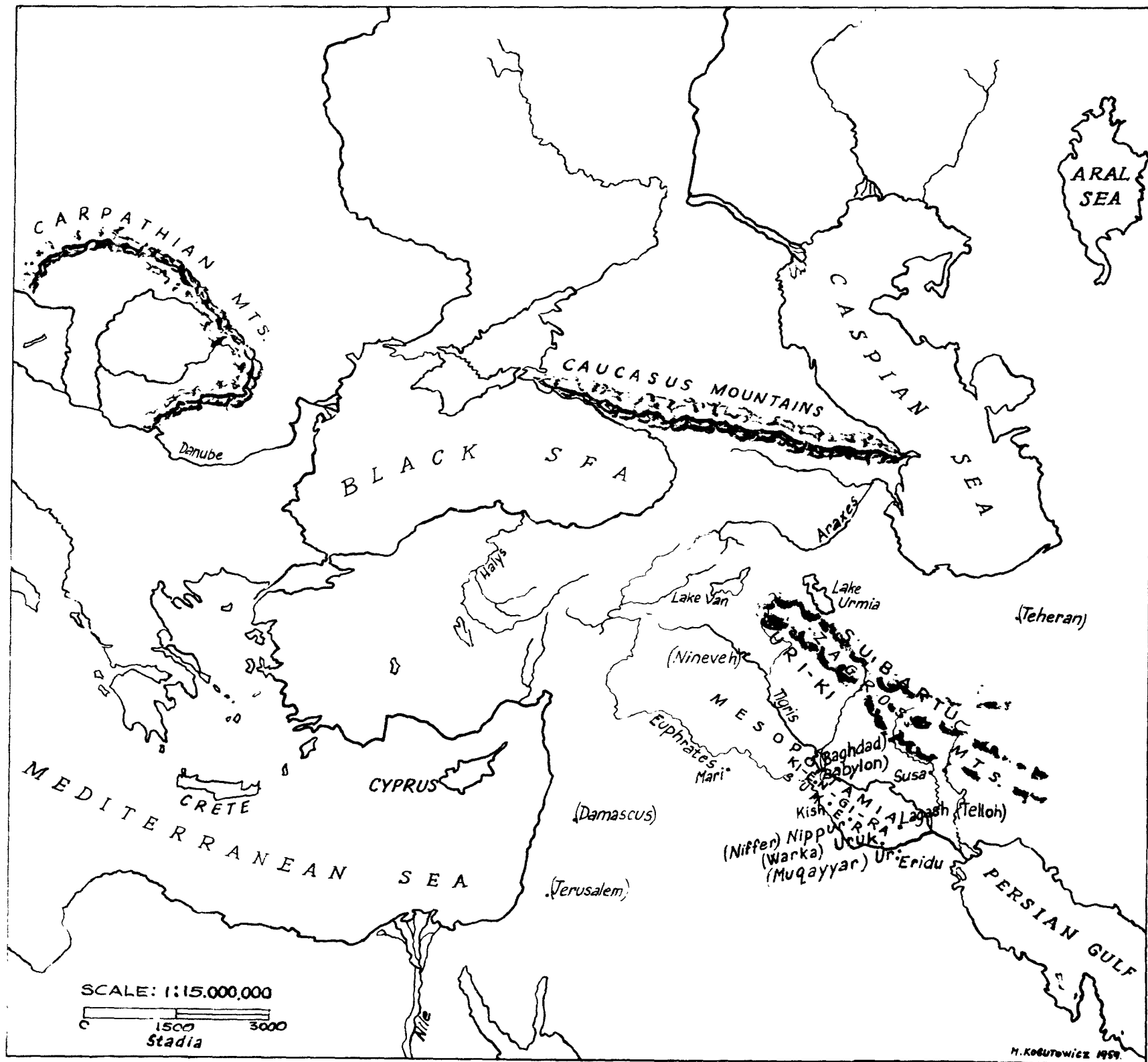


FIGURE 1.—Map of Sumerian cities in the third millennium B.C. and the surrounding territories.
Names of later cities in parentheses.

Sumerian Technology

A SURVEY OF EARLY MATERIAL ACHIEVEMENTS IN MESOPOTAMIA

By IDA BOBULA

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[With 12 plates]

INTRODUCTION

DURING THE PAST hundred years the spadework of devoted archeologists has reopened for us in Mesopotamia the buried record of mankind's first great civilization. The face of a forgotten people has reappeared from a perspective of four millennia. But even after it had been generally accepted that this people made the tremendous invention of the written word, Orientalists had not yet agreed upon a name for them. French scholars, recognizing that



FIGURE 2.—Impression of seal cylinder, which belonged to a woman, representing the goddess Baba, "Lady of the Mountain," with a devotee.

this was the group whose direct heirs are called Chaldeans in the Bible, began to use the name Chaldean for the rediscovered people. Later the name Accadian was used by many savants, but after a vigorous controversy among scholars, in which the very existence of this ancient group was first hotly denied by some, then definitely established, there emerged a general agreement to call this ancient people Sumerians.

The discovery of the Sumerians brought many surprises; their material and moral civilization appeared, in the light of the exhumed documents, far higher than anything expected from a group of such antiquity. The few scholars who were able to recognize Sumerian achievement across the span of millennia, in spite of a script hard to decipher and a mysterious agglutinative language, expressed their admiration in no uncertain terms. Stephen Langdon,



FIGURE 3.—Seal of Ur-Engur, king of Ur city. The earthly ruler is depicted as presented by benevolent goddesses to the moon god.

in the first volume of the Cambridge History, writes that human civilization begins with the Sumerians and that they were the most talented and humane of all known early peoples. And indeed, Sumerians were talented. Without doubt, we owe to them the invention of cuneiform signs from which developed the Phoenician alphabet and the principle of writing, the means by which man may speak to fellow men across the ages.

We know, also, that the Sumerians were nonaggressive. Though sometimes obliged to defend their homeland from barbarian onslaught, they were not hostile to others. Keen and warm-hearted observers of nature, they directed their energies in the service of human life against the destructive forces of nature. Their irrigation system, completed in the fourth millennium B.C., created unprecedented wealth and freed "the shaven-headed people" from want. Sir Leonard Woolley, discoverer of ancient Ur, in his book on the Sumerians (1928), voiced "the claim of Sumer": if any people can be regarded as "first cause" of civilization, that people is the Sumerian.

Excavation on Sumerian sites, Tello, Warka, Nippur, and especially Ur, dating back to the third millennium B.C., revealed the antiquity of some of our technological processes. Radiocarbon tests helped to establish the earliest dates of human history. It became obvious that many great inventions credited to later nations must be traced back to



FIGURE 4.—A masterpiece of early engraving represents Ninurta-Gilgamesh, the mighty hunter, on a jasper seal cylinder.

Sumer because the corresponding artifacts such as the wheel, or constructions like the arch, occur first in the Sumerian sites. The only legitimate claims for contemporary achievement by another people may be those of the Egyptologists, but even these claims are often questionable. It is of course possible, though not probable, that an earlier wheel than the Sumerian may be discovered in India or Iran, as Gordon Childe (1951) emphasizes. But until this actually happens, we have to accept the "claim of Sumer" on this "most decisive factor of the industrial revolution" and many other achievements.

The nontechnical "firsts" of the Sumerians recently received some publicity. Dr. S. N. Kramer (1956) selected from the clay tablets of Sumer a number of "firsts": the first law code, the first love song, and the first grumble against the tax collector known in human history. There are also the first proverb, the first city map, the first medical prescription, and the first account of a schoolboy's day, all shedding light on the way of life of the Sumerians. Here and there allusions have also been made to the inventions of the Sumerians in the field of technology, although these were never listed in spite of the fact that the excavations of recent years have brought new proof of the amazing technological knowledge and skill of these



FIGURE 5.—From seal which belonged to Gudea, *patesi* of Lagash; the shaven priest-prince receives for his people the most precious gift from the Lord of the "Water of Life."

stocky Mesopotamians. The present study attempts to give a brief review of the high points in the long succession of basic innovations, inventions, and achievements of the Sumerians in various fields of technology, as far as these may be identified by archeology and by the existing documents. It is the aim to present the merits of the Sumerians, those builders of the first high culture in Eurasia, who have to be recognized sooner or later as the real source of Western civilization.

CANALIZATION AND AGRICULTURE

The first achievement of the Sumerian people was the canalization of the land between and around the two great rivers, the Euphrates and the Tigris. This feat created the proverbial riches of Mesopotamia.



FIGURE 6.—Deities of agriculture, with plow and produce, engraved on cylinder seal.

—the first man-made plenty and variety of food, thanks to easy transportation and exchange. Canalization provided good grazing grounds for cattle and sheep, as well as breeding waters for fish. Caught with metal harpoons and hooks and easily available to the whole people, fish remained for a long time the basic source of protein for the Sumerians. Vegetables and fruit, grown systematically, rounded out the healthful Sumerian diet.

The digging of navigable canals, which bring irrigation water to desert sands and make agriculture possible, cannot be attributed to a few geniuses, but must have been supported by organized groups

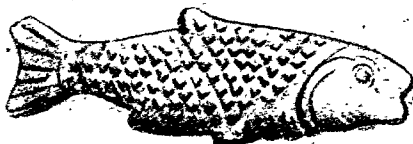


FIGURE 7.—Goldfish amulet of Queen Shubad.

of people, coaxed into concerted effort by the first statesmen and economists, aided by the first engineers able to draft plans. It is estimated that the majestic network of Mesopotamian irrigation was ready by 4000 B.C., the inscriptions of later kings boasting about

additions and repairs which were obviously regarded as highly meritorious work.

Irrigation made methodical agriculture possible and produced fodder for the flocks of a settled people. Sheep, cattle, and pigs were bred in abundance by skilled herdsmen. "The carefully irrigated fields did yield amazing crops of barley and spelt; onions and



FIGURE 8.—The legendary hero overcomes and tames wild animals. Seal.

other vegetables grew along the canal banks and as early as 2800 B.C., the date gardens were very extensive—a number of varieties of dates was cultivated and the harvest afforded one of the staple foods of the people," said Sir Leonard Woolley (1928). Date stones were ground for fodder or used as fuel in the smelting furnaces. Oil was pressed from sesame seed, and it seems that there were mills for grinding large amounts of grain, although we do not know how they worked.

The vegetables mentioned in Sumerian tablets are squash, gourds, eggplant, beans, lentils, cucumbers, chick-peas, leeks, garlic, cress, mustard, lettuce, capers, and some roots, probably turnips, radishes, and beets. Many spices were used: aloe, fennel, anise, fennugreek, coriander, thyme, marjoram, mint, rosemary, turmeric, ginger, saffron. One unidentified spice plant was the *šimbir*. All these were carefully gathered and preserved—the old records tell us of an "overseer of the house of herbs," also of a man who is by trade a maker of



FIGURE 9.—Archaic seal depicts plowing.

ointments. Small gold models of pomegranates used as jewelry show that this fruit was known. Almonds, plums, cherries, pears, mulberries, apples, figs, grapes, quince, citron, and pistachio are mentioned.

We have long, elaborate legal treatises on clay tablets, which regulate the mutual rights and duties of a landowner and of a gardener who undertakes to plant date palms on the land of the former. The tools of farming—the spade, the hoe, the plow, and irrigation machinery—are mentioned first in Sumerian texts. One tablet records 4,638 worn copper sickles and 60 old hoes sent from the hardware house to the smithy to be sharpened.

The world's first farm bulletin, written in Sumerian, was found in 1950 among the ruins of the city of Nippur. This bulletin instructs the farmer about the different kinds of furrows, tells him to "keep an eye on the man who puts in the seed, have him put the seeds in two fingers deep uniformly" with the seeder, a plow which carried the seeds and planted them through a funnel-like attachment. The tablet discusses the additional value of three irrigations against the necessary two, and advises the farmer to say a prayer, too, lest mice and vermin destroy the crops. For a long time the rational advice was followed, the prayers were said, and the land of Mesopotamia was the most blessed spot on earth.



FIGURE 10.—Impression of early seal illustrates the idea of plenty: "Grain and cattle."

ARCHITECTURE

The marshlands of Mesopotamia offered only the poorest raw materials to the building trade of the first groups of human beings who settled there, certainly longer than 5,000 years ago. From mud and reeds the Sumerian builders created monumental architecture that must have been not only strikingly beautiful, but sophisticated as well—suited to a people who shaved, bathed, and used silver manicure sets long before Abraham's days.

The clay of the marshes can be fired into bricks, and brick was used by the Sumerians when large buildings were to be erected. Stone, which had to be imported, was used only for special purposes such as door sockets. The vast ruins of the Mesopotamian mounds contain mostly bricks. Square bricks, more seldom oblong bricks, formed foundations, walls, even the pavement of the streets. In later buildings, the planoconvex brick appears, flat on one side, convex on the other. In the early strata, large bricks of real cement were excavated. But the art of mixing cement seems to have gone out with the kings of Ur. Cement for plastering is used in the Royal Tombs of Ur, but after that the art was forgotten.

It is certain that the ancient Sumerians also utilized the giant reeds for building. The reed decays in a few decades, but Sumerian

gem seals have preserved pictures of the reed houses. It is probable that the airy, cool reed house was the usual habitat of the poor people, and perhaps some of the wise, simple priest-princes, the Magi, also preferred it on hot Mesopotamian nights.

In the marshes of the lower Tigris and the Euphrates, Marsh-Arabs are still building beautiful large halls as well as small huts from giant reeds, artfully bound and fashioned into columns and arches. Small streamers sometimes hang on top of the reed columns of such build-



FIGURE 11.—Archaic seal with drinking ritual, before a door, possibly a marriage ceremony. Eagle and stags in the lower register.

ings, and one cannot ignore the fact that the symbol of Innin-Ishtar, the great goddess, was a doorpost or column with a streamer. A doorpost with a streamer, a piece of woven material, may have been the age-old symbol of a home, a habitation in which there is a woman who weaves, and a hearth, under a roof held up by a column, symbolizing the protection of Ishtar-Hestia-Vesta.

Private dwellings, originally built of bricks and wood, were found and reconstructed on the streets of the ancient cities. Such houses seem to have been mostly built around an open court, giving to families and individuals the privacy which was neglected in later millennia. Modern architecture is making an effort today to recapture this lost value.

Judging from the remnants of these houses, their walls were thick, the rooms not too large, but lofty; there were brick stairs, domestic chapels, kitchens, and lavatories with efficient drains of terracotta pipes. The builders seem to have respected the contemporary omen, probably inspired by a regard for privacy, inscribed on a tablet: "Rooms opening out of each other are unlucky but those opening on the court bring good luck." According to the excavator, "The houses bespoke comfort and even luxury." Considerable knowledge of architecture must have been evolved in Ur, even for the building of galleries and two-story houses, but of course more of it is evident in the planning and execution of the public buildings.

We know that Sumerian architects drew plans of the contemplated buildings and built accordingly. This is attested by a statue of Gudea in the Louvre, showing the priest-prince of Lagash holding in his lap the plan of the temple he built.

Earlier, far more primitive glyptic representations show rulers carrying on their heads the basket of the masons, all evidence pointing to the fact that, while the later Assyrian rulers paraded usually in the role of formidable warriors, the Sumerian rulers wanted to convey to posterity the idea: "We were builders." And so they were. Among others, the early dynastic Temple Oval, excavated by P. Delougaz, was built according to a remarkable plan.

Sumerians placed all their buildings, temples, palaces, office buildings, treasuries, and libraries, on artificial platforms built of brick and bitumen, several yards high. The platform was constructed over soil hardened by filling and stamping and called *temen*—the word from which the Greek *temenos* and our *temple* originate. The reason for the platform is obvious—in the flat riverland protection from floods was necessary.

In the great public buildings of the Sumerians, the excavators have found all basic elements of classic architecture—the colonnade, the arch, and the vault. In the ruins of many public buildings have

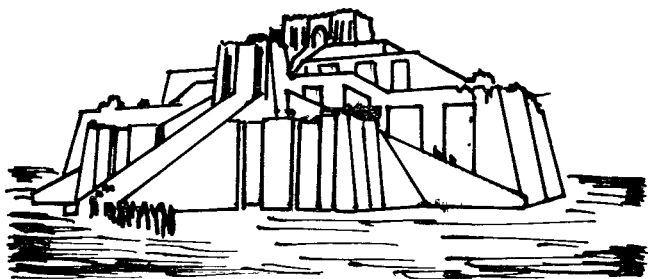


FIGURE 12.—The *ziggurat* (temple hill) of Ur, reconstructed.

been found carefully waterproofed boxes with foundation deposits, statuettes, and tablets—messages to posterity. Five such deposits were buried under the Inanna temple of Nippur, excavated in 1956.

After Woolley's discoveries at Ur, the invention of the arch could no longer be attributed to the Etruscans or Assyrians. While there are in Egypt some ancient arches of an age comparable with those of Sumer, there the arch had neither the importance nor the frequency of application which this architectural element had in Mesopotamia, where the available building units, the bricks, were small and necessity would have prompted the invention.

R. A. Jones (1941) suggests that Sumerians may have chanced upon the invention of the arch by the burning of the arched reed top

of one of their reed buildings, when the mortar which covered the reeds was burned into a monolithic arch. If we may accept this explanation, we may also speculate as to whether the first "Gothic" cathedral was a mortar-covered reed building with the reeds burned out. The present-day reed buildings of southern Mesopotamia cannot fail to evoke in the spectator the feeling of affinity with the best Gothic style. The round "Roman" arch has certainly stood in its classic beauty and perfection over doors overlooking the lowlands of Mesopotamia for many millennia from the ruins of Ur, antedating the founding of Rome by a long stretch of time. The influence of Sumerian art on that of Rome is demonstrated in the book of Jurgis Baltrusaitis, "Art Sumérien—Art Roman" (1934).

Woolley (1935) discovered that, in their transition from the square plan to the round plan of the half dome, the Sumerian builders used a rough spherical triangle in the corners of the room as support for the dome. He gives credit to the Sumerian architects for the invention of the pendentive, which is generally believed to have been developed in the Byzantine Age.



FIGURE 13.—Imprint of marble cylinder worked with revolving burr. Animals and architectural detail.

It would be a great injustice to Sumerian builders not to recognize that they strove for beauty. We must remember that the more delicate touches of decorative art which we miss today on the remnants of the nude brick walls of the Sumerian buildings may have been there in perishable material—wood and textiles. Heuzey (1888) suggests this possibility and mentions the cedarwood and the rugs. Sumerians seem to have enjoyed the subtle play of harmony and contrast of materials and colors. They were the first to use the mosaic technique. But their essential achievement remains the masterful use of rhythm in the proportioning of their buildings.

CERAMICS AND GLASS

The fine clay carried to South Mesopotamia by the two great rivers was not only the basic material of architecture—foundations and walls, floors and drain pipes—but in a country completely void of stones, clay hardened by fire had to be used for making primitive tools, and in the deepest layers in which artifacts are found in Mesopotamia, clay objects are already abundant. Characteristic tools of the earliest agricultures are clay sickles, some of them with inlaid flint teeth. Along with these come the earliest clay statuettes of the first divinities.

Naturally the largest number of clay sherds came from broken

vessels. The vessels found in the deepest layer were hand turned and delicately painted. The artifacts of this oldest culture, called Al-Ubaid, are covered by the 8-foot-thick clay layer of the flood, and above it come remnants of vessels, unpainted, but robust products of the real potter's wheel. At some time in the age called that of the Uruk culture, the potter's wheel was invented, obviously to provide for the needs of a rapidly increasing population. Fragments of the actual potter's wheel were excavated at Ur. Clay provided the Sumerians with jugs with which to feed their babies and water their plants. It was also made into dishes for banqueting; bowls, cups, chalices, squat jars, highnecked jars, large jars for holding and for storing water, oil, and grain. Cof-fins, too, were sometimes made of pottery. It seems that in certain cases the clay statues of the gods were toasted with clay cups, the latter being afterward smashed—this is the explanation given for tons of broken pottery in the temple of Abu at Tell Asmar. No wonder that the Sumerian language abounds in expressions for different types of vessels.



FIGURE 14.—Figure of winged goddess from clay plaque. Nippur.

The wooden frame which made the mass production of uniform brick possible, and also the firing of bricks, were inventions of major importance. Sumerians had a special god in charge of brick-making; his name was Kabta.

Clay was used for making many toys, and clay dice were found, dated to the First Dynasty of Ur, which are exactly like modern dice. Clay was the cheapest material with which to fashion traylike gaming boards, probably for the same games that the princes played on boards covered with engraved shells and precious stones.

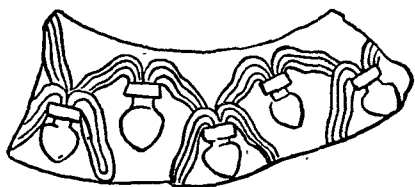


FIGURE 15.—Fragment of carved stone vase from Lagash, with a succession of spouting vases.

The world's first city map is preserved on a clay tablet; a carefully drawn and perfectly recognizable map of the ancient Sumerian city of Nippur.

However, the most important use of clay in Mesopotamia, from the point of view of the historian, is the clay tablet for writing. Tens of thousands of such tablets have been unearthed in Mesopotamia, covered with cuneiform writing. These texts, incised with a



1. Head of Sumerian ruler's statue, from Lagash. The hard stone, diorite, was worked in the round, ca. 2000 B.C. (Courtesy Museum of Fine Arts, Boston.)



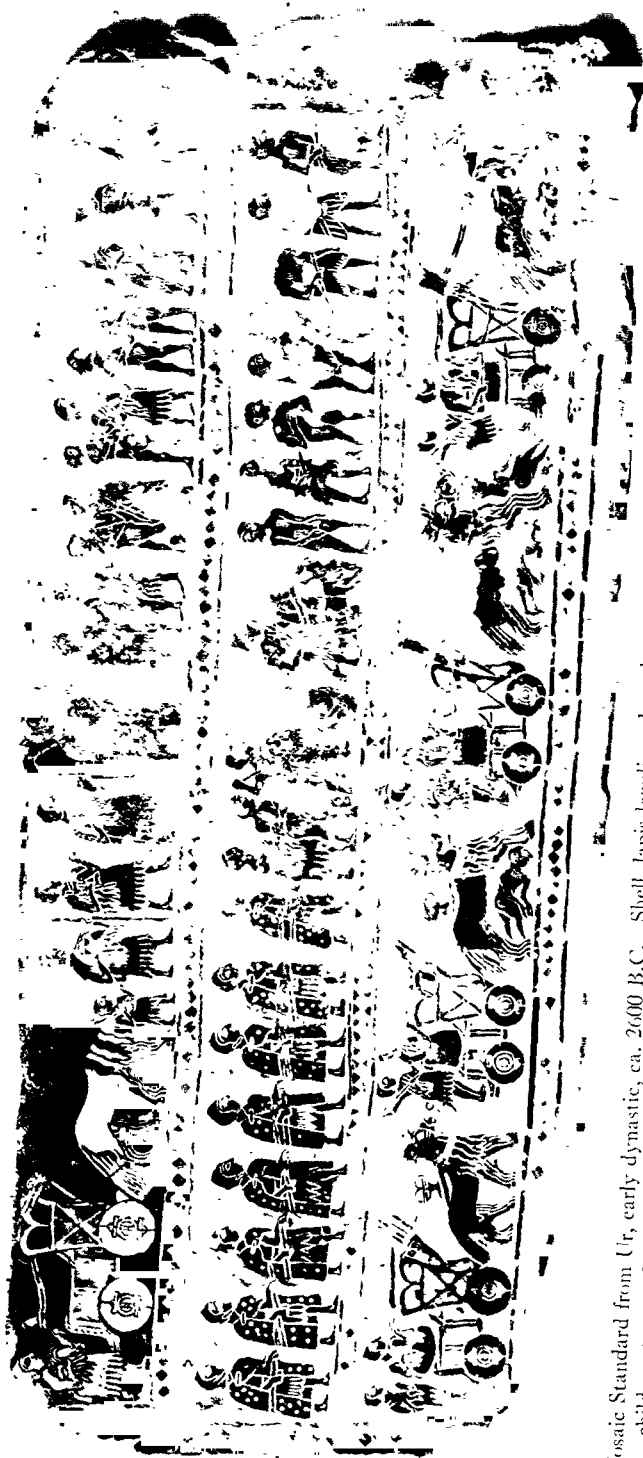
2. Archaic marble head, dated ca. 2800 B.C., from the ruins of Uruk, "Eternal City" of the Sumerians, dedicated to the cult of Inanna, goddess of love, who, according to legend, descended to hell, was killed, but, sprinkled with the "Water of Life," arose on the third day. (After Bohtz, 1941, pl. 1.)



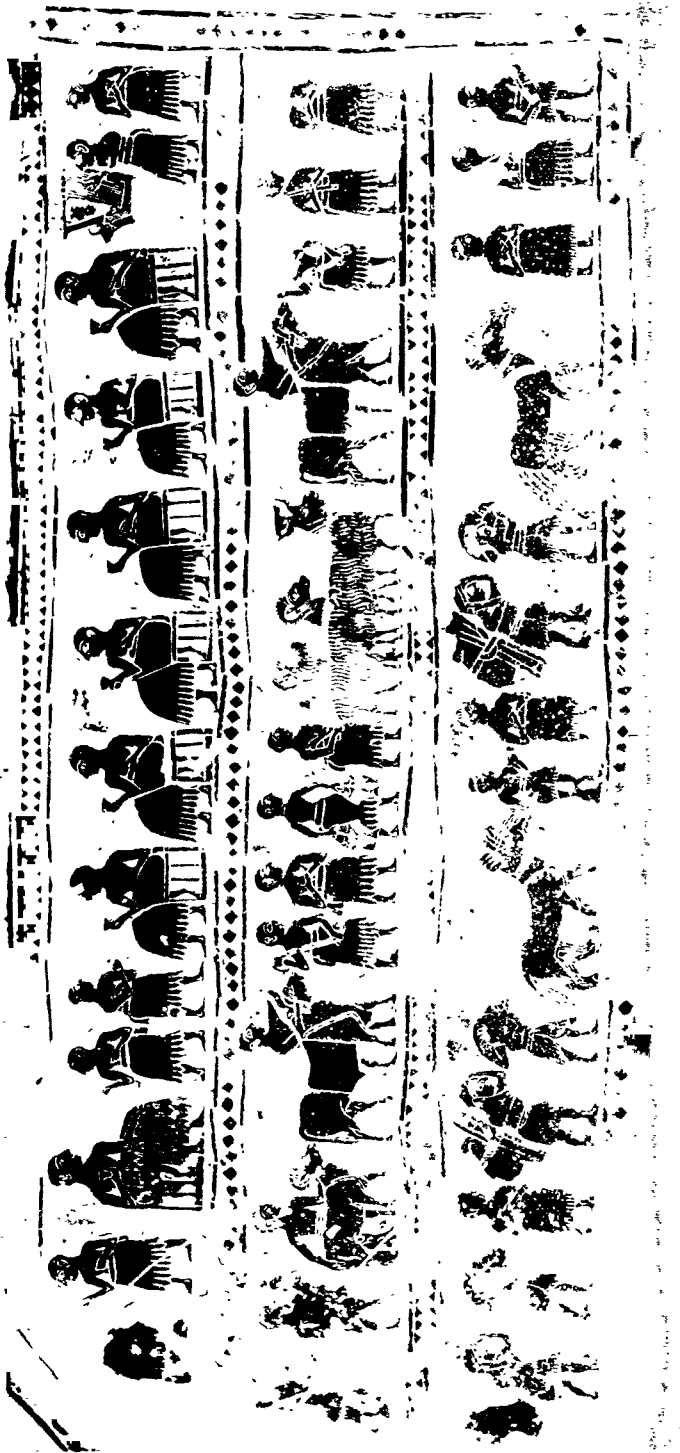
1. White marble head with inlaid eyes of lapis lazuli, from Ur, ca. 2000 B.C. (Courtesy University Museum, Philadelphia.)



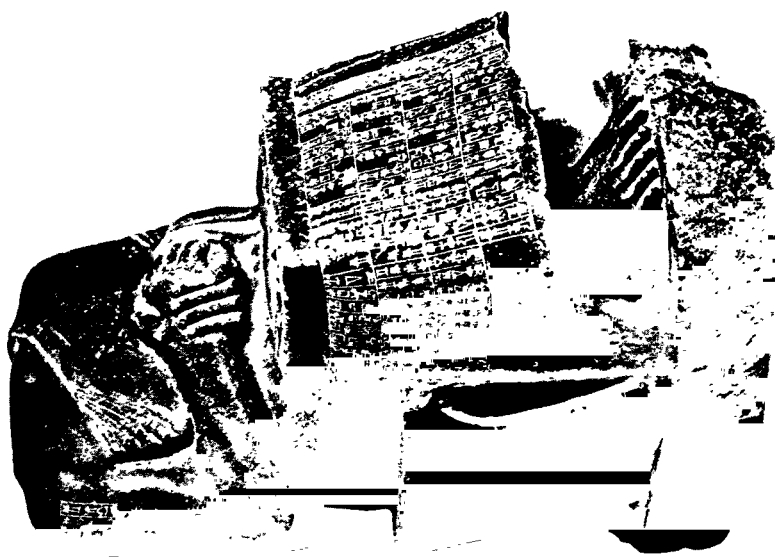
2. Head of Ur-Ningirsu, ruler of Lagash, carved in brown alabaster, ca. 2150 B.C. (Courtesy Metropolitan Museum of Art, New York.)



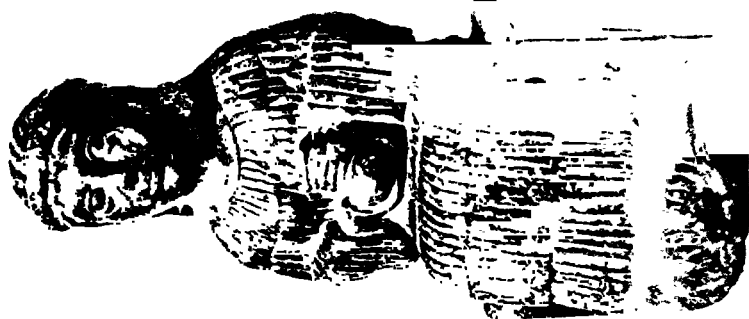
Mosaic Standard from Ur, early dynastic, ca. 2600 B.C. Shell, lapis lazuli, and sandstone inlays on bitumen foundation show scenes of war. "Even the child went out to fight," relates the top register. "The braves donned their heavy leopard-skin coats and their helmets, and carried their national weapon, the 'toothed' adz. The battle chariots broke the enemy's force and the army of Ur took many prisoners."



Obverse of the standard of Ur, showing the joys of victorious peace. Banqueters enjoy drinks and music provided by harpist and singer, while fish and animals for meat are brought in plentifully. The men are shaven, except one of the servants; they wear the fringed *gadda* garments. (British Museum.)



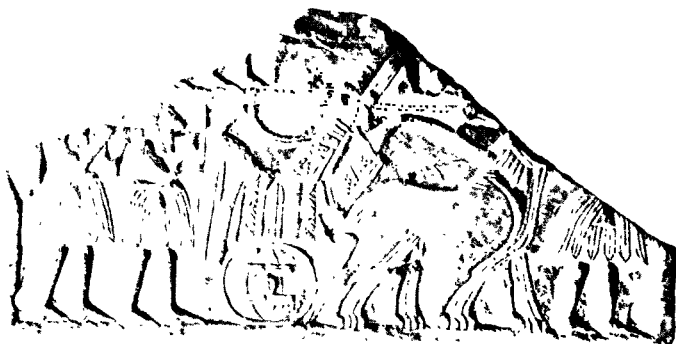
1. Blue diorite stone statue from Lagash, now in the Louvre, called "Gudea the Architect." (After Sarzeo and Heuzey, pl. 14.)



2. Stone statuette of enthroned lady, holding vessel, wearing simple yet sophisticated gown of flounces and pleats. In the Louvre. (After Heuzey, pl. 5.)



1. Stone monument of King Ur-Nammu, founder of the Third Dynasty of Ur, ca. 2060 B.C. Libation propitiating deities of the date palm, the "tree of life." In the lower register the king carries the tools of the temple builder; his code is the first known code of law.



2. Fragment of limestone relief from Ur; the oldest representation in art of a wheeled chariot, dated ca. 2500 B.C. The chariot is covered with the symbolic, spotted leopard skin. (Both objects in University Museum, Philadelphia.)

reed stylus and then fired, varying from important historical texts or poems to all kinds of everyday accounts, give us more insight into the everyday life of Sumer than that which we get from Greek or Latin documents on peoples who lived much later.

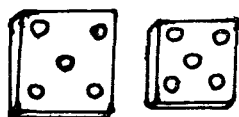


FIGURE 16.—Clay dice from Ur.

For many centuries, the Phoenicians were credited with the invention of glassmaking; a story was current about their fortunate chancing upon this important invention. The modern excavations exploded the fable and made it clear that both the Egyptians and the Mesopotamians made glass long before the advent of the otherwise highly gifted Phoenicians. In early Mesopotamia glass occurs mostly as material for beads of glass paste, but in Nippur a small glass bottle also was found.

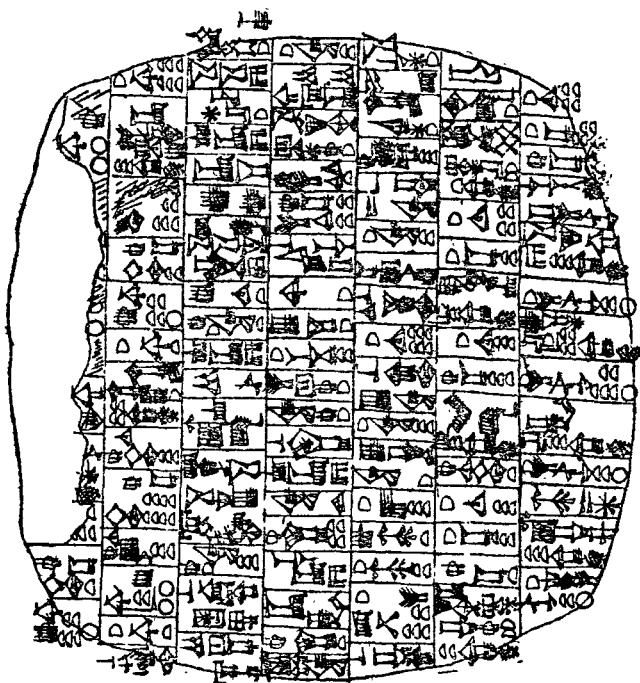


FIGURE 17.—Clay tablet with cuneiform script. (d: Genouillac, pl. 15.)

BITUMEN TECHNOLOGY—MOSAIC WORK

Bitumen is a mineral pitch, a naturally occurring solid or semi-solid substance, related in chemical composition to crude petroleum. Bitumen and petroleum usually occur in the same vicinity. Natural bitumen seeps out of the earth in many places in Iraq, and it is near those ancient fountains that man first learned to use this versatile material.

In the life of these early people, bitumen proved to be a most useful substance. It is pliable, resilient, and hardens in time; it is an adhesive; it can also be used for insulating and waterproofing. The earliest food stores, the underground silos of Hassuna village, south of Nineveh, were coated with bitumen. The early agriculturists of Hassuna and those of Jarmo, a settlement of even greater antiquity, used bitumen for toolmaking. Bitumen was the adhesive that held flints in the wooden hafts of tools, especially sickles used to harvest wheat and barley some 7,000 years ago.

At the hands of the Sumerians the humble mineral pitch became a material of prime importance. It was the material that bonded the particles of artificial mountains, the ziggurats like that of Ur; it held the burnt bricks together; it insulated the buildings, covered the pavements, and lined the boats made of reeds. Later, at the time of the Neo-Babylonian rule, Nebuchadnezzar recorded in his inscriptions that he fortified the walls with bitumen and covered with glistening asphalt the roads of Babylon.

Bitumen made possible the evolution of mosaic pictures. One of the most important achievements of early Sumerian art is the Standard of Ur, which comes to us from ca. 2600 B.C. One side shows an army going to war in leopard-skin coats, wearing helmets and carrying adzes, driving 4-wheeled battle chariots, which trample the enemy underfoot. The other side shows a peaceful feast—the participants wear only the fringed loincloth, the *gada*. They eat, drink, and listen to the singer and the harpist. This work of art, salvaged and preserved with infinite care by the hands of British scholars, is now the pride of the British Museum. A fine reproduction is in the collection of Mesopotamian pictures by Christian Zervos (1935).

The oldest specimen of inlaid pictures comes from Al-Ubaid; it is the famous frieze of white cows, calves, and stocky Sumerians processing milk around the sacred stall gate of the goddess Inanna, contrasting strikingly with a black shale background. This frieze is dated to ca. 2800 B.C.

STONE CUTTING

As all stone objects found in southern Mesopotamia are made from imported material, it is little wonder that much care was taken in carving and embellishing these precious objects. Stone door sockets of temples were usually marked with cuneiform signs; millstones were important economic assets. One of the Sumerian weapons, perhaps the oldest one, used by kings and often dedicated to gods, was the stone mace. Sacred traditions seemed to demand stone vessels with which to honor gods and royalty. Marble, alabaster, and carnelian were carved into vessels of exquisitely harmonious, simple shapes.

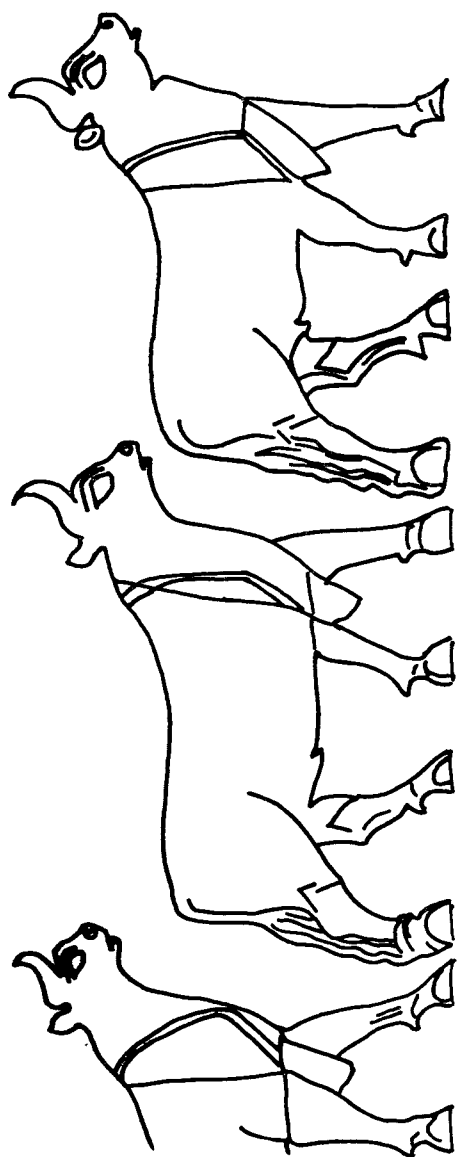


FIGURE 18.—Bull frieze, early inlay work. Al Ubaid.

Lapis lazuli, the dark blue semiprecious stone, was one of the most popular materials for inlaid jewelry, beads, and cylinder seals, though this stone, like diorite and obsidian, had to be imported from distant lands.

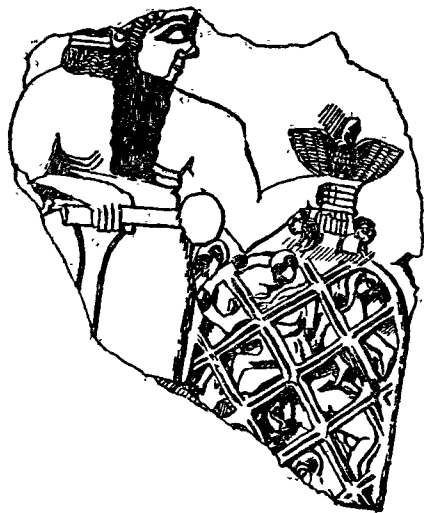


FIGURE 19.—Fragment of stone stela; the thunderbolt god Ningirsu with eagle and stone mace.

The cylinder seal, a large cylinder-shaped carved bead which the owner wore also as a proud ornament, was one of the original Sumerian inventions. Every seal was engraved differently; there are no two seals with identical designs. The design of the seal symbolized the owner and marked his property. A jar of oil or wine or a barrel of



FIGURE 20.—Royal cylinder seal.

corn could be closed with a stamp of wet clay; the seal was then rolled over it and this print identified ownership. Documents written by scribes on wet clay were affirmed by the seals of the contracting parties. Naturally, the design had to be sophisticated enough to be unique. Seals and impressions are so abundant in Mesopotamian sites that Legrain (1951) calls their collection "one of our most constant and

reliable indices of the changing aspects of art and culture during almost three thousand years." It is characteristic of the inner structure of Sumerian society that even the



FIGURE 21.—Ram carved of lapis; amulet of Prince Mes-Kalam Dug.

slaves, male or female, had their seals, i.e., they had lost their freedom, but not their identity. The idea of printing with cylinder seals is essentially identical with the principle of the giant cylinders of our printing presses: both perform the mechanical reproduction of a pattern. The history of printing begins with the cylinder seal.

The art of the gem cutters of ancient Ur produced artifacts of surprising and, in this field, unsurpassed beauty. The sculptors of statues were more handicapped by their material; nevertheless, they met the challenge.

It is from small blocks of the imported stone that Sumerian artists carved their statues, impressive portraits of men and women of long ago. Quite often a large head sits on a Lilliputian body; there was not enough stone to carve whole life-size statues, and the head was favored. But some of these statues from the third millennium are

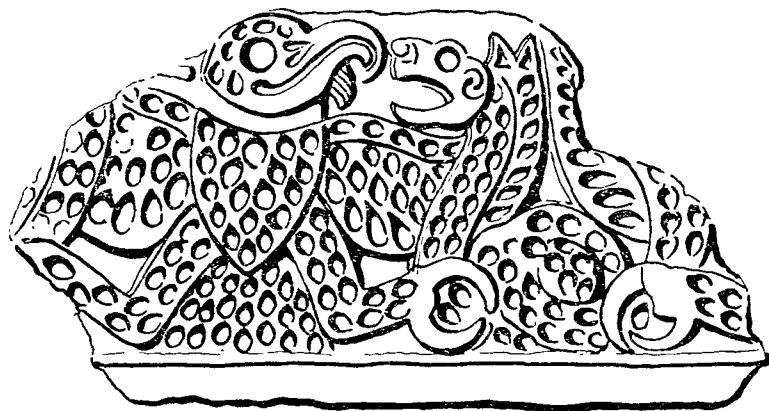


FIGURE 22.—Fragment of soapstone vase, from Nippur. (National Museum, Istanbul.)

quite realistic and in matter of beauty are above archaic Greek art. To mention three examples: the alabaster head in the University of Pennsylvania Museum, the Boston head, and the hauntingly beautiful "Lady of Warka." The French orientalist Leon Heuzey (1902) compared the art of the Sumerian sculptors with that of their Assyrian followers, who worked many centuries later. He found that the Sumerians surpassed in this respect the later empire builders. Sumerian sculpture is characterized by two marks of mastery: working in hard stone and working in the round. Heuzey's judgment is

supported by that of James Henry Breasted (1916), late director of the Oriental Institute of the University of Chicago, who wrote, "The early Sumerian lapidaries soon became the finest craftsmen of the kind in the ancient Oriental world and their influence has not yet disappeared from our own decorative art." Seton Lloyd, a contemporary authority on art and archeology writes also (1955) that the Sumerian statues are masterpieces which rival the work of almost any period in the history of art.

The engravers and stone cutters also used shell. A steatite bowl, artfully inlaid with shell flowers, is one illustration of this graceful art, and a gaming board of engraved shell squares encased in silver also was found at Ur. Shell was often used as inlay in the statues; the eyeballs were carved of shell, which turned gold-brown with age. The irises were sometimes made of lapis lazuli disks, and the lifelike colors give a powerful charm to these old portraits.



FIGURE 23.—Engraved shell plaque from a gaming board. Animals locked in combat.

METALLURGY

Plinius the younger, the Roman scholar, tells us that according to Aristoteles, the art of smelting and working copper was invented by a Lydian called Scythes. A blurred tradition seems to point here in the direction of western Asia. Far more tenuous speculations have been printed in our time about some unknown people having developed metallurgy at an uncertain date in Asia Minor. Two experts of the Metropolitan Museum, Bowlin and Farwell, write (1950) that "The great discovery [of bronze casting] probably came first in southwest Asia around 3000 or 2800 B.C. Egypt reached a bronze age by 2500 and the Greek world by 1500 B.C." Parts of northern Europe did not achieve this stage of evolution until many centuries later. P. Rousseau (1956) in his "Histoire des Techniques" states unequivocally that bronze was a Sumerian invention. It seems probable that the place where the firing of clay objects originated and the technique of the



FIGURE 24.—Fragment of stone relief from Lagash: Divinity with harpoon.

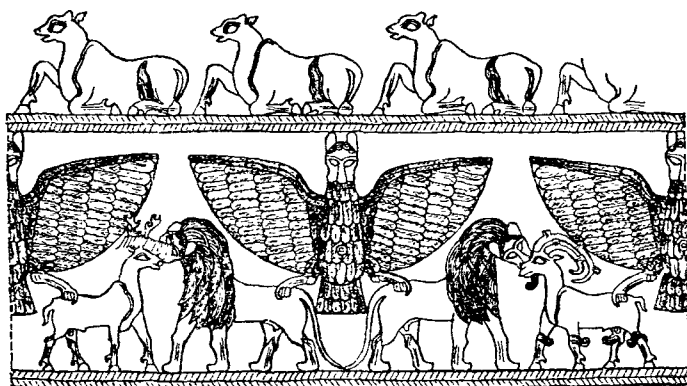


FIGURE 25.—Design from engraved silver vase: Lion-headed eagle and quadrupeds.

potter's kiln developed was the natural location for the development of the smelting furnace.

Rich copper deposits, available for smelting and casting copper and bronze, occur in the mountain districts of western Asia—Anatolia, Armenia—whence, as many scholars believe, the Sumerians descended into the plains of southern Mesopotamia. But they never forgot the mountain lands, source of all blessing. The goddess Nin-Hursag, the Lady of the Mountain, reigns over the sacred hills, which are expressly stated to yield gold, silver, and bronze. Gordon Childe (1928) states that the Sumerians also made large implements from iron. The mountain mines supplied the craftsmen of the lowlands with precious raw materials—gold, silver, copper, and tin—and the earliest masterpieces of the metalworker known to humanity are certainly those that have come to light from the Royal Tombs of Sumur.

In these wonderful collections of the earliest art, metals are used plentifully for vessels, weapons, tools, and jewelry. Sheets of metal were also used to cover beams of temples and statuettes of wood and bitumen. Metal heads of animals decorated sledges, musical instruments, and furniture. Shell-shaped silver lamps lighted the grave of Queen Shubad. There were many tools—chisels, saws, harpoons,

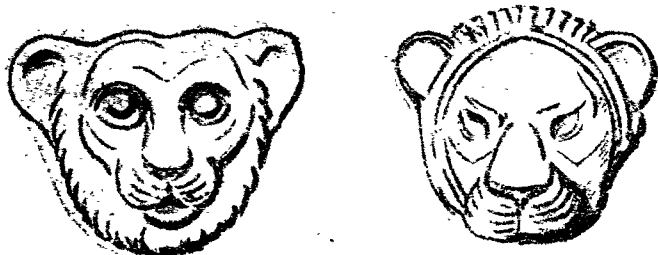


FIGURE 26.—Gold lion heads, which decorated the chariot of Queen Shubad.

knives, and razors. Mirrors and small, delicate gold and silver manicure sets were also found. Prince Mes-Kalam-Dug was buried with a spear of copper stuck into his grave; an electrum axhead was at his right shoulder. A beautiful copper relief, now in the University of Pennsylvania Museum, was hammered from a copper sheet in repoussé work. Lead rings were sometimes gold plated. Sheets of metal were nailed to cores of wood with small nails, as in the case of a copper horn discovered at Tello (Lagash).

Graves of the more important personalities contained vessels of metal in quantity. Some of these cups and bowls are beautifully shaped and fluted, sometimes engraved. The cups had obvious ritual importance; one was usually placed in the hands, near the mouth of



FIGURE 27.—Gold amulets of the queen.

the dead, probably with the hope that a benevolent divinity would some day pour into them the drink of life. To the category of vessels belong the long tubes of metal through which the Sumerians sucked beer from large jars.

The weapons of the Sumerians were the mace, the spear, and the dagger, a sickle-shaped sword, the bow and arrow, but especially the socketed and "toothed" pickax or adz. A poem written in cuneiform signs celebrated the creation of this national weapon by the war god for his chosen people so that they may build cities with it, but also keep malefactors in their place.

Woolley (1950) describes a gold dagger as "a wonderful weapon, whose blade was gold, its hilt of lapis lazuli decorated with gold studs and its sheath of gold beautifully worked with an openwork pattern derived from plaited grass." With this dagger was found "an object scarcely less remarkable, a coneshaped reticule of gold ornamented with a spiral pattern and containing a set of little toilet instruments, tweezers, lancet and pencil also of gold . . . they revealed an art hitherto unsuspected."

Gold was used for much of the jewelry worn by men and women—beads, rings, bracelets, earrings, chains, cylinder seals, headdresses, and bands. It is probable that there was plenty of filigree silver jewelry, too, but most of it perished in the earth. In a specially fortunate instance, a silver hair ribbon came to light in the folds of the robes of a court lady who died at Ur; the ribbon survived because it remained in a coil. The owner may have hurried in order not to be left out of the mass funeral, and she had no time to put on her ornament.



FIGURE 28.—Gold bird with lapis tail.

Larger silver objects had more chance to survive the passage of millennia, though their restoration was difficult. The silver from Ur was encrusted with a thick layer of silver chloride, some so-called secondary silver from which copper had been leached out, and in some cases with copper.

A. Kenneth Graham wrote (1929) :

... to reproduce the silver bowl (of Ur) would require no ordinary amount of skill even with modern methods. The silver alloy would first have to be prepared and cast into convenient form. It would then be alternately heated in a furnace (annealed) and rolled until a flat sheet of the desired thickness is obtained. The silversmith would carefully study the shape of the object to be produced and then proceed to cut a pattern out of the flat sheet metal. He would then prepare forms upon which the metal would be hammered to the finished shape.

Microscopic examination of the structure of Ur silver showed that indeed this was the way in which these old silver objects were made, and they are technologically "worthy accomplishments."

While gold objects usually take care of themselves, restoration of silver is the glory of the museum experts, and ingenious methods have been developed by which today's master craftsmen pay tribute to those of the past, while proving, and allowing others to realize, how great was the mastery of these early metalworkers, who produced masterpieces of unsurpassed beauty.

Let us once again quote from Sir Leonard Woolley, who describes the helmet of prince Mes-Kalam-Dug:

It was a helmet of beaten gold made to fit low over the head with cheek pieces to protect the face and it was in the form of a wig, the locks of hair hammered up in relief, the individual hairs shown by delicate engraved lines. Parted down the middle, the hair covers the head in flat wavy tresses and is bound round with a twisted fillet. . . . As an example of goldsmith's work this is the most beautiful thing we have found . . . and if there were nothing else by which the art of these ancient Sumerians could be judged we should

still, on the strength of it alone, accord them high rank in the roll of civilized races.

CHEMISTRY

Who was the first chemist? Probably the man or woman who discovered that heat makes some kinds of food tastier. The first achievements of applied physical chemistry were most probably connected with food. From these modest beginnings evolved further progress. Gordon Childe, the Australian scholar and excavator, stated (1958) that all early kilns to fire pottery developed from the prehistoric



FIGURE 29.—Offerings of food are brought to the goddess, who holds the symbol of life. Seal.

bread-baking oven, and the potter's kiln may well have been the ancestor of the smelting furnace. M. E. L. Mallowan, one of the great archeologists, describes (1930) the beehive-shaped bread ovens and the cooking ranges with flat, fired-clay tops and circular flues of the Sumerians.

Refined cookery always bespeaks a highly evolved old culture, and this was the case in Sumeria. The Sumerian lexical material has a number of expressions which could be used only by gourmets. Judging from the beauty and variety of their dishes and cups and the many monuments portraying banquets and symposiums, they were a convivial people with a robust *joie de vivre*, which gave important place to the pleasures of the table.

Our earliest records of food come from the Sumerians, who certainly knew how to roast meat and fish and cook vegetables, how to grind flour and meal, knead dough, bake bread, churn butter, press oil from olives, make wine from grapes, and ferment barley for beer and dates for some sweet, strong drink.

Small grinding stones were still in the brick-floored kitchen of the high priestess in the temple of the goddess Ningal at Ur, when the Joint Expedition of the University of Pennsylvania Museum and



FIGURE 30.—Man and woman drink beer from one vessel, through long tubes. A third person raises his hand in blessing.

the British Museum (1927-57) discovered it. Maybe breads and cakes were made here, about which we read in later inscriptions; these were needed for ritual purposes. It seems that for the benefit of field and garden, seven breads were needed, made with oil, honey, flour, and sour cream. The Mesopotamian recipe in cuneiform resembles that of the festive cake called *mézeskalács* still made in Hungary. The Sumerian cakes were cast upon the waters; again a ritual not unlike the one called *lepénvetés* which was followed up to some decades ago in Transylvania.

Recipes for making "heavy" beer, "black" beer, and "red" beer have been deciphered. Nineteen varieties of beer are enumerated in Sumerian texts. All these must have contributed to good cheer at the symposiums which seem to have been favorite high points in the life of the Sumerians.

To keep themselves young and beautiful, the Sumerian ladies resorted to cosmetics. Cockleshells were the usual containers for cosmetics and of these some are present in most of the feminine graves. The cosmetics, of which traces have survived for thousands of years, were paints, the powdered remnants of which kept their colors; they may be white, black, blue, or red, but according to Sir Leonard Woolley (1950), "the normal colour is green." Queen Shu-



FIGURE 31.—Box for cosmetics, made of silver, engraved shell, and lapis.

bad used green paint, perhaps to match green eyes. She had not only large natural cockleshells for her cosmetics, but imitation shells, too, one of gold and another of silver. She kept her kohl or stibium, her black paint, in a box made of silver, engraved shell, and lapis lazuli. L. Legrain (1929b), another member of the team which excavated Ur, relates that "calcite vases, half empty, show on the surface of the black cosmetic the print of dainty fingers dipped in it centuries ago."

A chemical analysis of these cosmetics, made by Kenneth Graham (1929) soon after their discovery, states:

One sample of what appeared to be a light blue clay was found to contain large quantities of aluminium phosphate, copper, lead and carbonate, with traces of iron, calcium and silica. One would conclude that this was powdered turquoise, a naturally occurring mineral consisting of hydrated aluminium phosphate with the usual copper impurity in sufficient quantity to color it blue.

A second sample of black powder, similar to antimony or "kohl," was found upon analysis to contain a large amount of manganese and lead, with small quantities of copper, aluminium, phosphate, carbonate, silica, and iron. The last six substances were evidently present as turquoise, as described above; the black colour could only be attributed to the manganese, the black oxide of which is a naturally occurring mineral, pyrolusite.

The presence of lead and carbonate in both samples is quite unexpected, as they are not associated with either turquoise or pyrolusite in nature and must have been added purposely. The oxides of lead are coloured and when mixed with the above minerals in powdered form give attractive shades of brown, red and purple.

The expert adds that the presence of lead in the cosmetics was a serious health hazard. This raises the question: did Queen Shubad of Ur and her lady friends risk lead poisoning, or did they have besides the poisonous paint some kind of neutral foundation cream that protected the skin from the poison? At any rate, one feels that the fabrication of such sophisticated toiletries is a sign of extraordinary achievements in chemistry.

There are no direct indications that the Sumerians knew and used soap. But we may infer this knowledge from the fact that men shaved their heads and faces, a process which would have been too painful without soap. The second point to consider is the name "soap" from the Latin *sapo*, both reminiscent of Sumerian *zeeb*, which meant "beautiful." Soap was a cleanser, hence a beautifier.

To soap and paint, we must add perfume—this was probably in the form of a scented, spiced ointment, called *ir*, a transitional product between cosmetics and medicines. Sesame oil, butter, and sheep's fat were sent from the temple stores to the *ir* makers; these must have been their raw materials. There were many medicines, and we have inherited on clay tablets a number of prescriptions which seem to utilize ingredients coming from the mineral, zoological, and botanical realms. The favorite minerals were sodium chloride (salt) and potassium nitrate (saltpeter). The powdered wood of some fruit trees, such as pear, fig, and date, as well as of willow and fir, was used for healing. We do not know what plant was called "moon-flower" by the Sumerians, but among their medicines cassia, myrtle, thyme, and asafetida may be identified with reasonable certainty. What the Sumerians called *gamun* and the Accadians *kamun* is probably the same herb that we call cumin.

VEHICLES

The excavators of Ur were awed to find among the earliest Mesopotamian sculptures a limestone relief depicting a wheeled chariot. "The plain wheels are made of two semicircular pieces, joined by copper clamps round a central core. The wheel, a great human discovery, was in use at Ur more than fifteen hundred years before it was imported into Egypt," said one of the early reports published by the University of Pennsylvania.

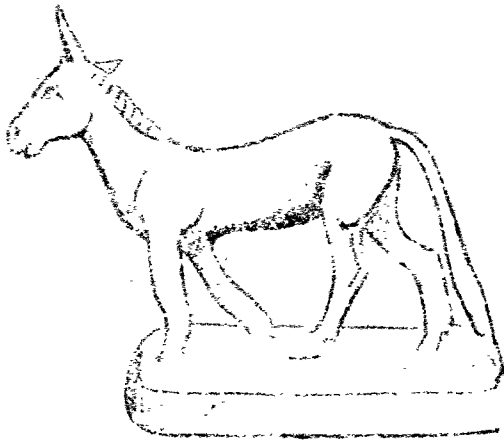


FIGURE 32.—Electrum mascot from the queen's sledge.

Soon the real wheels of the archaic period came to light, in the Royal Tombs of Ur, in Kish, and Susa. They were the wheels of four-wheeled chariots. The earliest indication of the use of wheeled vehicles is a pictograph sign in one of the oldest written documents of humanity—a clay tablet from the temple of the goddess Inanna in Uruk dated to ca. 3500 B.C. The wheels of clay model chariots were first found in the Uruk stratum, though the earliest known picture of a wheeled vehicle is on a seal impression of the Jamdet Nasr age. Sir Leonard Woolley (1955) credits the epoch-making invention to the people of the Sumerian temple city Uruk (Warka).

In the years following the excavations, feeble but repeated efforts were made to blur the picture and raise doubts about this outstanding achievement of the Sumerians. In opposition to such efforts, a body of experts working on the five-volume pioneer study of Oxford University's *History of Technology* reached the conclusion that the wheel was most likely invented about 3500 B.C. in Lower Mesopotamia, and that it was an original invention.

There is every reason to suppose that the boat was an even older vehicle than the chariot. The clay model found in a man's grave

at Eridu, was called "probably the earliest model of a sailing ship" (Lloyd, 1948b). The earliest Sumerian graveyards yielded silver, copper, and clay models of boats. We know from inscriptions that the Sumerians undertook boat voyages of several years, cruising to obtain luxuries from far lands for their temple-states. Sailcloth for boats was woven in the highly organized workshops of the temples.



FIGURE 33.—Archaic boat. Seal.

If we accept the opinion that the thought is the father of the deed, then we must remember, when speaking about aviation, that the first story about a man ascending in the air on wings was the ancient story of Etana, told on a tablet and illustrated by several carvings on cylinder seals, some dating to the Akkad period. Etana was a good shepherd, who, when his flocks and his wife were stricken with barrenness, went to search for an herb, source of life.



FIGURE 34.—Cylinder illustrating man's first attempt to fly.

He mounted an eagle and rose up in the air, but when near his goal, he was hurled back to earth. This legend is the earliest known tale of flying by man.

CLOTHING

Leather seems to have been the main material from which Sumerians made their clothing in the oldest times, when they lived in a cooler mountain land. Sheepskins protected them from bitter winds, and it is probably the ancient tradition which survives in the sheepskin caps worn by later princes like Gudea and Ur-Ningirsu. The

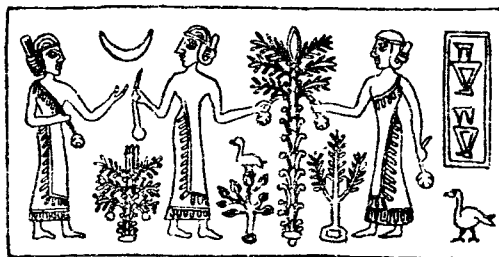


FIGURE 35.—Ladies' wearing apparel, from seal cylinder.



FIGURE 36.—“Migration scene,” on seal of king of Uruk, in Sargon’s age. Men wore boots when they had to migrate.

statuary has transmitted to posterity the carefully carved curls of baby lambs on these early specimens of headwear, from which many later shapes developed. The archaic, original form of this sheepskin cap is still worn unchanged by peoples of Eurasia, who inherited or borrowed customs from the Sumerian civilization. Heuzey (1888) calls the hat one of the important Sumerian inventions.

It seems that the men of the army, when going to war, wore a special coat made of spotted leopard skin. This military garment is clearly visible on the Standard of Ur. Leather was probably used for archaic kilts, belts, headdresses, and footwear.

Leather perishes in the course of millennia, but many written references to leather objects survive. Leatherworkers are often enumerated in the lists of craftsmen such as the long list given by Dr. Anna Schneider (1920) in her book on the Sumerian temple city. Statues of kings, usually destined to stand in temples, are as a rule barefoot, in pious humility, but boots are sometimes apparent on cylinder seals.

Wool, another animal product, was certainly used by the Sumerians. We know of many references to wool being shorn, transported,

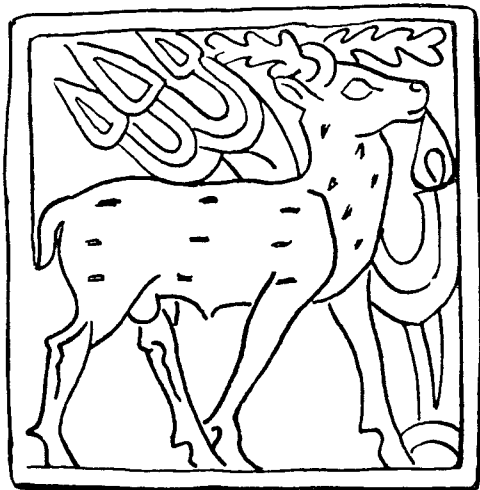


FIGURE 37.—Fallow deer, engraved on shell plaque.

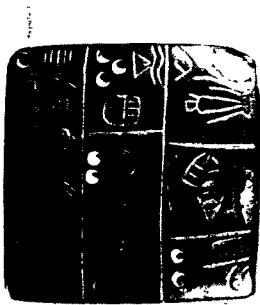


1. (left) Fragment of stone statue in the Louvre, representing probably the goddess Nidaba, or Nanshe, of reeds and fishes, also of writing and all cultural and charitable activities. She was in charge of widows, orphans, and refugees, and of punishing injustice. (Courtesy Archives Photographiques, Paris.)

2. (right) Alabaster vase in the Guennol Collection, lent to the Metropolitan Museum of Art by Mr. and Mrs. Mastair B. Martin. The cowlorn pair, attribute and symbol of the fertility goddess, evolved in later ages into the "horn of plenty," characteristic of Asiatic-Greek Kybele, the great mother goddess. Ultimate refuge of the symbol is the folk art of central Europe, where it hides under the assumed name "tulip." (Courtesy Metropolitan Museum of Art, New York.)



1. Fragment of black stone vase in the Louvre; Libation, the ritual act of watering the Tree of Life. (Courtesy Archives Photographiques, Paris.)



3. Stone tablet with early and still not clearly understood pictograph signs of writing. Record of a sale of land. (Courtesy University Museum, Philadelphia.)



2. Beaded headress of queen Shubad, from lapidary head-dress of queen Shubad. (Courtesy Archives Photographiques, Paris.)



The Ram of Ur, animal portrait executed in the first half of the third millennium B.C. with great mastery, on core of wood and bitumen, from hammered gold sheet. (Courtesy University Museum, Philadelphia.)



1. Bull's head from the great lyre of Ur, gold and lapis lazuli. (Courtesy University Museum, Philadelphia.)



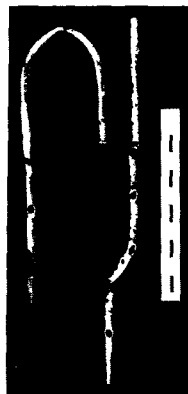
2. Bronze head of a bull, with inlaid eyes, dated ca. 2600 B.C. (Courtesy City Art Museum, St. Louis.)



1. Copper vase statue of neo-Sumerian king, bearing a basket of bricks for the building of a temple. (Courtesy Metropolitan Museum of Art, New York.)



2. Archane copper relief from the Al Ubaid temple: Lion-headed sun-disk and stags. (Courtesy British Museum.)



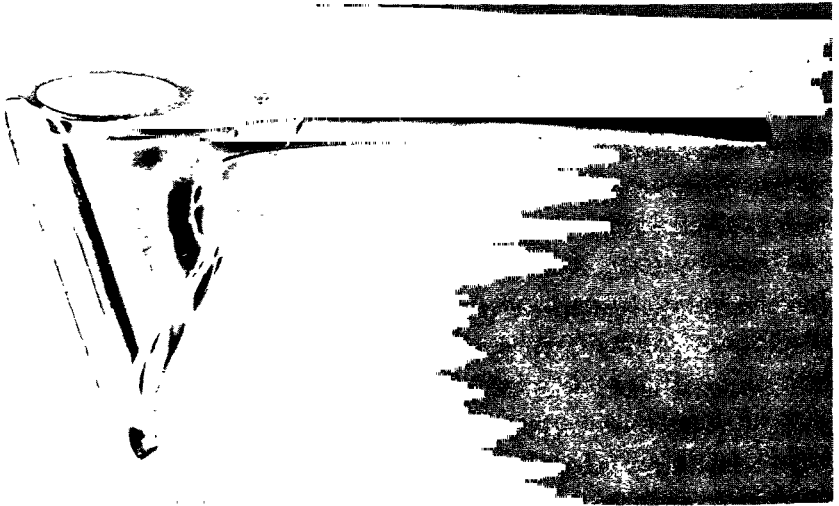
3. Silver flute from Ur. (Courtesy University Museum, Philadelphia.)



4. Reconstruction of the ancient double flute by Jesse-Phillips Robertson.



1. Gold vessels of queen Shubad, from Ur, ca. 2600 B.C.



2. Socketed gold adz from Ur, the beloved and celebrated special weapon of the Sumerians.
(Courtesy University Museum, Philadelphia.)

sold, or delivered to the temples, where groups of workers did the spinning and weaving. The magic texts of healing tell us about the spinsters of the goddess of love, Inanna, who spun "black wool, white wool, mixed wool, wonderful yarns." Such yarns were also used to "bind sickness."

Wool was tinted. The great ladies wore on festive occasions coats of bright red wool, tiny powder-fragments of which survived in the graves. However, linen was also known, and there is every reason to believe that linen was the everyday wear in the hot climate of Mesopotamia. Temple accounts enumerate common, hemmed, and splendid linen. The simple skirtlike garment of the men, which left the body above the belt uncovered, is worn by the relaxed banqueters of the Standard of Ur. Women's bodies are almost always completely covered with flounced skirts and fringed shawls. A long evolution of weaving and spinning techniques must have preceded these sophisticated textiles.

The earliest textiles of humanity were probably those made from water plants. Every child who has access to plants growing in marshland starts pleating and weaving them. This primitive and natural technique must have evolved into the later forms of spinning and weaving wool, hemp, and linen. The loom was already known in the early Al'Ubaid culture, as shown by the surviving stone weights. In the time of the royal graves, the art of weaving, dyeing, and sewing was already fully developed. Some of the court ladies went to their death in elaborate sleeved coats.



FIGURE 39.—Gold miniature of stag, from the queen's beaded headdress.

The ancient art of weaving large, beautiful shawls survived for a long time in Mesopotamia; there are references to it in classic literature. The Greeks called these shawls *kaunakès*. When the Sumerians disappeared, their high textile art, radiated into the surrounding areas, seems to have been revived in many places. The legend of the arch-spinner, Arachne, localized to Lydia, seems to indicate that the Greeks learned the art from that direction. Arachne, daughter of Idmon of Colophon in Lydia, was, according to the myth, so skilled in weaving that she

dared to challenge the goddess Athena to a contest. Arachne won, but frustrated, angry Athena changed her into a spider.

The most primitive textiles, the ancient reed mats and baskets, also survived, made by the inhabitants of Mesopotamia in unchanging patterns as long as there were Sumerians and even long after they departed. Reed mats were used for wrapping the bodies of the poor for simple burials. Woolley (1950) writes:

It is an astonishing thing that in soil wherein so much that seems enduring decays entirely, a fragile thing like a piece of matting, though it lose all its substance and can be blown away with a breath, yet retains its appearance and its texture and can with care be exposed in such condition that a photograph of it looks like one of the real matting which perished 4,500 years ago.

MUSICAL INSTRUMENTS

Music, like dancing, had ritual aspects in the early days of Sumer.

The harp . . . and the clang of cymbals accompanied the chanting of prayers in Sumerian temples. The small harp was sufficient for the private chapel of the queen. The magnificent harps of gold and silver discovered of late in the royal tombs must have been used in official ceremonies. . . . The cymbals of Shubad's time [ca. 2500 B.C.] were flat metal pieces, straight or horn-shaped, which the dancers struck in cadence. They are seen in the hands of the kid dancing behind the scorpion man; in the hands of a cymbal player, on a gold cylinder seal of the high priestess buried in the domed vault discovered last winter; in the hands of a woman musician of the Kish inlaid plaques. Curiously enough, the museum has two such plates of copper brought from Fara 30 years ago . . . most likely Sumerian cymbals of Queen Shubad's age. They are curved, 35 centimeters long and 4 in width at the larger end. (Legrain, 1929b.)

The large drum, which is often depicted by Sumerian lapidaries, also must have been an instrument of ritual music; later texts speak of driving away the evil spirits with the sound of the drum.

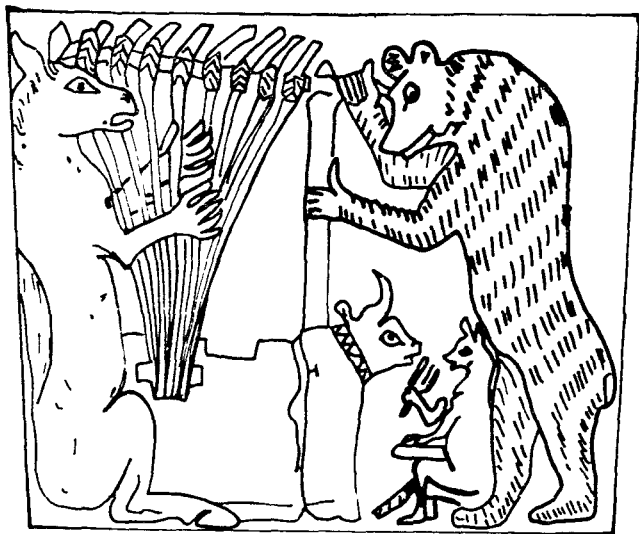


FIGURE 40.—Masquerade; animals as musicians. Inlay picture on a large harp from Ur.

Kiengira, the "Holy Land of Reeds," was the original name of Sumer. A reedland would be the natural home of the reed pipe. We do not know of any reed pipes which could have survived the ordeal of entombment for thousands of years, but the University of Pennsylvania possesses a fine pair of silver pipes, called sometimes "a double oboe" (pl. 11, fig. 3).

The same museum is the proud owner of two wonderful Sumerian harps, lyres, and crosses of these two types. Woolley (1950), who found many of them at Ur, describes them thus:

One of these harps was the most magnificent that we have yet found; its sounding box was bordered with a broad edging of mosaic in red and white and blue, the two uprights were encrusted with shell and lapis lazuli and red stone arranged in zones separated by wide gold bands, the cross-bar was half of plain wood, half plated with silver, shell plaques engraved with animal scenes adorned the front and above these projected a splendid head of a bearded bull wrought in heavy gold. [Pl. 10, fig. 1.]

A second lyre in the same place was all of silver, with a cow's head, a third with a stag, and a fourth with two stags. Woolley wonders,



FIGURE 41.—Scorpion-man and kid dancing.

were the instruments of "different sorts, the bull denoting the bass, the cow the tenor and the stag perhaps the alto? Then the finding of four lyres together in one grave might imply a system of harmony, which, at this early date, would be of a very great interest for the history of music."

Musical instruments are depicted on Sumerian steles and other stone fragments, shown in table 426 of Christian's (1940) *Altertumskunde*. There were bells, rattles, sistrums, and a great variety of primitive and sophisticated instruments.

The Oxford History of Music (Buck, 1929) begins with a chapter on Greek music, followed by a second chapter, "Music of the Hebrews." In these and the following chapters, it is acknowledged that all Greek music had its origins in Asia Minor and that the characteristic and celebrated musical instruments of the Greeks and Hebrews are known from ages long preceding the times of those peoples. But these facts are told only in the footnotes. There we read about the Sumerian *kithara* represented on a bas relief from Tello, which is now in the Salle Sarzec of the Louvre; "as pictured, this kithara evinces a high standard of craftsmanship and theoretical knowledge."

The same source, speaking of the remote origin of the lute, mentions the smallest member of the family, the tamboura, which figures on a bas relief coeval with the above-mentioned, coming also from the palace of Gudea, Sumerian ruler of ancient Lagash. We may add that Donald E. McCown excavated at Nippur in 1952 a clay plaque with the figure of a man holding a lute.

The number and diversity of surviving musical instruments and the cuneiform documents mentioning different types of songs are witnesses to a fairly high musical culture in Sumerian cities between the third and the second millenniums B.C. One wonders if scholarship will ever proceed to the point of reconstructing and reviving the music of the Sumerians? A courageous effort was made by F. W. Galpin (1937).



FIGURE 42.—Mountain goats; engraved shell plaque.

CONCLUSION

From architecture to music, all arts and crafts of today owe a certain debt to the ancient masters of Sumer. The present brief sketch of Sumerian achievements in the field of technology is far from exhausting the field, nor was this even attempted. Yet we cannot conclude this review without mentioning two important branches of human activity, from which the technical know-how is inseparable: the sciences and the art of healing.

It has been stated and far too often repeated, more or less explicitly, that the human communities preceding the classic period of antiquity lived in the darkness of despicable black magic and superstition. This is not a fair picture; there has certainly been an evolution in

human knowledge, but it has been a slow transition and there is no sharp dividing line between earlier western Asian and later east European wisdoms.

A closer look at the world of these very ancient Magi discloses that their "magic" was founded on the carefully collected and transmitted sum of observations made by the type of men whom today we would call scholars. Many generations of Magi observed the facts of weather, the march of the stars, the changes of the seasons, the phenomena connected with plants, animals, and human beings, and they combined these observations.

The Magus was the man who had observed the fact, or received in secret teaching the important information, that when the sun's disk ascends between the horns of the constellation Capricorn it means the end of winter. The force of the sun returns, the days are lengthening, and he may preach to a depressed people the good news of the coming of the spring, the end of winter's misery.

Men and women able to predict the changes of weather, ever so important to primitive peoples, were the first scientists; their knowledge gave them power and raised them to the status of priest-princes. The source of this power remained for a long time the continued careful and ritual observations of the heavenly bodies and other natural phenomena that constitute astrology, the parent of modern astronomy.

Sumerian healing art was far from being silly superstition. Before suggesting therapy, the Sumerian physicians had to recite conscientiously the diagnosis. Their prescriptions, concocted from plants, animals, and minerals, given with beer as a chaser, sound quite rational as witnessed by a tablet in the University of Pennsylvania Museum which has been called the oldest page in medical history. This Sumer-

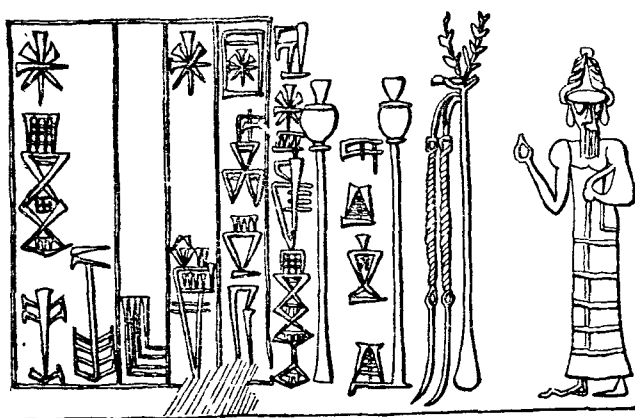


FIGURE 43.—The seal of a physician, on gray limestone cylinder.

ian clay document from Nippur is completely free from the mystical and irrational elements which characterize later Babylonian medicine. Sumerian medics had their medicines, but obviously they found it useful to add psychotherapeutic treatment.

One is surprised to read recent, lengthy books on the history of human civilization and the great inventions of mankind in which the authors ignore or persistently belittle the basic contributions of western Asia and especially those of the Sumerians. It is quite arbitrary to state that the Sumerians lived before philosophy began, or that their knowledge was not real "science." The early speculations of the Sumerians, embodied in their myths, on the essence, cause, and nature of things, are the foundation and beginning of philosophy. It is natural that, like all beginnings, these ideas are primitive. But it should be gratefully recognized that the Sumerians not only invented and developed the whole series of metal tools which artist and craftsman use even today for creative work—the adzes, chisels, saws, awls, drills, and many others—but they also created the basic abstract tools and categories of scientific work for today's Western scholar. Early Sumerian tablets contain enumerations of fishes, birds, domestic animals, and plants which the ancient writers observed and grouped. The categories they created laid the groundwork for such branches of science as zoology and botany. The basic operations in mathematics, including algebra, and our system of metrology are a legacy from the Sumerians. They taught us to measure length by foot, weight by pound, land by acre. They evolved the sexagesimal system, they divided the circle into 360 degrees, the day into hours, and the hour into 60 minutes. The tablets show that they knew and used the theorems later attributed to Euclid and Pythagoras long before the birth of these great Greeks. For a wealth of fascinating details the reader is referred to the bibliography following this article, which for technical reasons cannot be complete, but many of the books mentioned will give further references to other books and periodicals in the field.



FIGURE 44.—Procession of women. Seal cylinder.

Sumerian nature and thought do not appeal equally to all modern students, and many of the primitive speculations about *presages* and other irrational elements are obviously unacceptable. But mixed with these are elements of timeless value, and these should be recognized. Sumerian thought paved modern man's way in getting acquainted with his still puzzling universe.

ACKNOWLEDGMENTS

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By courtesy of the University Museum of the University of Pennsylvania are included figures 7, 21-23, 26-28, 32, 37-39, and 42, drawings originally made by Miss M. Louise Baker for the Museum Journal.

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Brandywine: An Early Flour-Milling Center

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[With 7 plates]

"FEW PEOPLE are at any considerable distance from gristmills," wrote St. John de Crèvecoeur of late 18th-century America. Fast-flowing streams, whirring waterwheels, and massive millstones, once a common sight, are now all but forgotten. Today an occasional gristmill survives, giving mute testimony to Crèvecoeur's observations and to the unimposing beginnings of a still important industry whose foundations were laid in the Delaware Valley along such creeks as the Wissahickon, Neshaminy, Pennypack, Crosswicks, Rancocas, Pensauken, Chester, and Brandywine. In fact after 1700, on most streams mills of every size and shape, supplied with an abundance of wheat from the rich farmlands of the Middle Atlantic region, met domestic needs as well as the demands of hungry markets in Europe and the West Indies. Philadelphia, New York, and later Baltimore thrived as flour ports and trade-conscious merchants eagerly purchased the product of nearby mills, hoping either to ship the barreled staple worldwide in their quest for the riches and goods of foreign lands, or to speculate on the domestic grain market which, in the 1750's, became lucrative for the first time (1).¹

Some mills ground solely for local needs and were called custom mills; others, larger and better equipped, ground specifically for the export trade and were known as merchant mills. The former were usually isolated and on the lesser creeks; the latter were often found in clusters, situated on the larger streams, where waterpower was ample and where transportation—by road or water—linked the mill to the wheatfields and the market. Occasionally, a combination of geography, waterpower, grain supply, and entrepreneurial skill produced milling centers of unusual capacity which for a time dominated the economic life of their locality. The Brandywine Mills, on the

¹ Numbers in parentheses refer to notes at end of text.

tidewater of the Brandywine Creek near Wilmington, Del., were such a center (2).

Here, in almost bucolic surroundings, successive generations of Quaker millers reaped handsome profits from the tons of flour that they shipped to the corners of the world. Here, too, the genius of Oliver Evans was put to work. By the 1780's his inventions—elevators, conveyors, descenders, and the hopper-boy—were clanking away in the Brandywine Mills, helping to improve quality, increase yield, and reduce the physical burden of milling (3). Evans's machines, at first dubbed "rattletraps," literally took the sack from the miller's back and, in so doing, revolutionized the flour-milling industry. Finally, as Thomas Twining pointed out in 1796: "Here America already exhibited a spot which might be compared with any similar scene in England" (4).

But what was so different about these mills, and why tell their story? There is reason enough if one reflects on a long-forgotten but, to the historian, a challenging appraisal; namely, that a study of the Brandywine Mills "would afford a complete picture of the rise of the milling interest in the United States" (5). A bit strong, perhaps, yet the Brandywine's story was retold with each westward move of the population. Wilmington and her mills became a prototype of later flour-milling centers.

One thing is certain, the history of Wilmington's flour mills is the story of a successful business venture. In Wilmington there were mill owners whose records—diaries, journals, and letters—help to clarify the methods of one early American industry; but, more than a chronology of a successful enterprise, the mills on the tidewater of the Brandywine were also a prime force in the industrialization of a town. Here, in the 18th century, a group of Quaker businessmen, functioning in a favorable political, economic, and geographic environment, made Wilmington a leading milling center. Their success encouraged imitation (6).

Before the end of the 18th century local businessmen had invested in paper, cotton, calico printing, snuff, and slitting mills located on the Brandywine near the town; similarly, in New Castle County, particularly on Red and White Clay and Mill Creeks, waterpower turned the wheels of a variety of infant industries (7). Early in the 19th century the Du Ponts had added extensive gunpowder mills, a woolen mill, and a tannery to the Brandywine's diverse industrial community; to many it seemed Wilmington was becoming "the *Manchester of America*" (8).

A stroke of geographic luck saved Wilmington from being an agricultural village. Located on the tidewater, and easily accessible to navigation, her mills supplied the staple that stimulated and

maintained her merchants just as the farms and mills of the region collectively motivated the trading interests of Philadelphia. The flour mills of Wilmington, generally referred to as the "Brandywine Mills," shared coequally with facility of transportation in making this Delaware town such an important adjunct of the flour trade that during the last quarter of the 18th century this community was "famous all over America for its Merchant Mills" (9).

The Brandywine Mills during the 18th century had few rivals, but in the following century real competition began for preeminence in the milling industry. The development of other merchant mills and new marketing centers considerably modified the repute of the flour millers at Brandywine. As the 18th century ended, the mills of the Ellicotts, at Ellicott City west of Baltimore, and the Gallego and Haxall mills, at the falls of the James River, were just commencing extensive activities. These mills, plus those at Rochester and Oswego in western New York State, expanded their operations as the Piedmont and back country areas became more heavily populated. When the wheat belt extended farther west, New York, Baltimore, and Richmond replaced Philadelphia as the chief marketing center and flour port in the United States; and simultaneously, canalization made the natural transportation facilities of the Brandywine less important than they were originally (10).

But how did it all begin?

In 1742 Oliver Canby, a Bucks County Quaker, moved to Wilmington seeking the opportunities which seemed abundant in a new place where Friendly ways were practiced and where members of the local meeting dominated the affairs of the town. Canby, a millwright by trade, realized the Brandywine's potential as a millstream and quickly began a milling business. In less than 15 years, Canby had gained control of important water rights and had built the first mill of size or consequence near the head of navigation on Brandywine Creek. Furthermore, during this period he had married the heiress of the town—Elizabeth Shipley. Canby's initial work was followed by that of Thomas Shipley, who, in concert with several others, managed to have a mile-long millrace dug and the four mills completed on the south bank of the creek at the tidewater. Now, for the first time, efficient use could be made of the waterpower so readily available and of the water highway which led straightway to the markets of the world (11).

But what of the little hillside village between the Christina and the Brandywine? In 1736 the itinerant Quaker Thomas Chalkley had predicted it would be "a flourishing Place, if the Inhabitants take Care to live in the Fear of God," always preferring heavenly reward to the material "Things of this World." Notwithstanding

Chalkley's prophetic admonition, Friendly ways led members of the local meeting to wealth, prestige, and influence, giving the town, if slowly, a thriving manufacturing and mercantile interest (12).

In 1744, 2 years after Oliver Canby had begun his milling business, Dr. Alexander Hamilton described Wilmington as having nearly "the largeness of Annapolis" but built more compactly with most of the houses of brick (13). Six years later the town exhibited some evidence of commercial life, although James Birket found local merchants in "such low Circumstances" that they could not "make any great figure" from mercantile pursuits (14). By 1754, the year Canby died, Lewis Evans described Wilmington as "a town of no small Trade" (15), but Governor Thomas Pownall thought it still lacked sufficient population or "trade enough . . . to compleat it to its plan" (16). The place impressed Andrew Burnaby in 1760 merely "as a pretty village" (17). In fact, not until the 1770's did Wilmington begin to have "all the appearance of one of the English country towns" (18), nor until this decade, according to Silas Deane, did the Brandywine Mills produce the quantity of flour necessary to "render it a large place" (19).

It was in the 1770's that mills similar to those promoted by Shipley were built on the north side of the stream directly opposite the older ones. These improvements were accomplished by the resourcefulness of Joseph Tatnall, Delaware's first great industrialist who, incidentally, was related to both the Shipleys and the Canbys. With the completion of the new mills a milling center was born and the future was bright. The next 20 years marked the consolidation of the early industrial and commercial development of Wilmington, and by the 1790's the Brandywine Mills were supplying a considerable amount of flour for the export trade. An "Infant place" had become the heart of one of the busiest centers of manufactures in the United States. In addition, a milling oligarchy had been firmly established, one that persisted until the 1920's (20).

The Brandywine Mills, tightly clustered about the tidal basin of the stream, increased in number from 8 to 14 between 1770 and 1820. During this period Oliver Evans introduced the idea of automation to flour-mill machinery; and subsequently the mills at Brandywine were mechanized, although work was still provided for scores of individuals including millers, millwrights, coopers, blacksmiths, and shallopmen (21).

The mills brought their owners a handsome profit. By 1800, 300,000 to 500,000 bushels of wheat were ground annually. The Quaker millers, in good years, reaped a return of a half-million dollars from their business, and local merchants shipped Brandywine flour worldwide. As a result of the flour trade, these merchants lined their shelves with the goods of foreign lands, and local residents enjoyed the

taste of chocolate, coffee, and good wine. The flour-milling industry, in every sense, was a large-scale enterprise, which preceded Du Pont's gunpowder manufactory as the industrial giant on Brandywine Creek (22).

The value of mills and mill property varied according to location, and in 1801 a mill upstream rented for much less than one on the navigable part of the Brandywine. Compared to a merchant mill at tidewater, a country mill in the interior was not worth much. Property near Wilmington cost \$22 to \$150 per acre, and in the early 1800's desirable millseats sold for close to the latter figure. The cost of land plus that of building a mill entailed a sizable expenditure. It was reported to E. I. du Pont in 1802 that the newest and finest of the Brandywine flour mills had cost "nearly 7000 dollars." This estimate was for a building of four stories, measuring "98 feet long by 48 wide and 40 feet high," and having "more stone under ground than in the walls" (23).

Not only were Wilmington's mills solidly built, but their owners were solid citizens as well. They championed abolition, care of the poor, penal reform, and internal improvements (roads, canals, and bridges) (24). Above all, during the Revolution they were patriots.

Family legend maintains that Joseph Tatnall told George Washington that "I cannot fight for thee, but I can and will feed thee." Good to his word, his mill ledger for the period reflects large amounts of flour consigned to Robert Morris, financier of the Revolution. Even Tatnall's home was used by George Washington, serving as his headquarters on the eve of the Battle of the Brandywine (25).

The flour-producing potential of the Wilmington area was of logistical import to both the British and American armies during the war. In the spring of 1776 a Quaker miller at Brandywine made a ledger entry that reflected not only the tenor of the times but also portended a change in the ordinary routine of the flour-milling business. Interspaced between the regular business notations for May 8 and 9, 1776, was recorded an account of "the Roe Buck, & Liverpooles Men of Warr & the 13 pensylvania Gunduloes," and their "Ingagement in the Delaware River Opposite Wilmington" (26).

It was not long after that General Washington was instructing his commanders to dismantle mills "which may be liable to fall into . . . [enemy] hands." And on October 31, 1777, he directed Gen. James Potter "to remove the running Stones from the Mills in . . . Chester and Wilmington." Five days after receiving the orders to remove the millstones, Potter wrote: "I'm a sorey to Inform your excelancey that the the Officer I send to the Brandywine Mills has not obay'd my orders. Instead of Taking the stons away he has taken the Spinnels, Rines and Ironnale heads. . . . I am Informed that Taking these Artecals answers the same end as Removeing the stons. . . ."

Washington's answer to Potter's misconception was twofold; first, to court-martial the officer who had failed to remove the stones, and second, to remove the millstones at once! Finally, on November 8, the stones were taken from the mills at Brandywine, and business there was temporarily suspended. By December 29, General Smallwood and his Continentals had reoccupied Wilmington and had received permission from Washington to put "one of the Mills to work" grinding "Flour and Horse Feed." Smallwood was reminded, however, to grind nothing in excess of "what you and the inhabitants may want." After the British evacuated Philadelphia in June 1778, restrictions were eased and the mills at Brandywine once again began normal operations (27).

After the war recovery was swift, and a succession of visitors, foreign and domestic, wrote of their impressions of Wilmington. The Comte de Ségur found it "a place of considerable commercial activity" in 1782 (28), and, by 1785, Elkanah Watson made a point to stop in the town "to examine the most extensive flouring mills on the continent" (29). In the same year a young London merchant, Robert Hunter, conveyed the impression of a healthy economy when he related that at Wilmington the flour mills "were never known to cease working, summer or winter" (30), to which Dr. James Tilton added that in really busy times the mills ground "perpetually day and night" (31). Francis Asbury thought Wilmingtonians were overly engrossed in politics in 1791; even so, little interfered with the business of milling, not even politics, although most of the Brandywine millers, unlike their Philadelphia brethren, were inclined to be Democrats (32). Few visitors were more succinct or more typically French than Moreau de St. Méry who, in 1794, looked at both Wilmington and her mills and said "magnificent" (33).

The 18th century was fast coming to a close when Isaac Weld visited the merchant mills at Brandywine. Unimpressed by the town, he was delighted by the mills where "no manual labour is required from the moment the wheat is taken to the mill till it is converted into flour, and ready to be packed" (34). Soon after Weld, the Duke de la Rochefoucault Liancourt also marveled at Oliver Evans's ingenuity as he toured the Brandywine Mills. In addition to these wonderful machines, Liancourt observed that the mills were "not employed for the public" but only for the "private service" of the owners. The mills at Wilmington were called a "flour manufactory" and were not unlike those at London Bridge and Paris; although Liancourt noted that the French mills were driven by a steam engine (35).

Robert Proud's "History of Pennsylvania" cited the flour manufactories on the Brandywine and Wissahickon Creeks as the best in America and "perhaps . . . not inferior in quality to any in the

world." The Brandywine Mills were especially well situated since shipping could come "up to the very doors of divers of them" (36). Soon after Proud's "History" appeared in 1798, the geography compiled by the German scholar Christopher Ebeling was published in Hamburg; and Europeans read about "the only town of any importance" in Delaware, and about the Brandywine Mills where "90,000 bushels of wheat" could be reduced "to nothing but fine flour" (37). Thus, both at home and abroad, the flour mills on Brandywine Creek were attaining some renown as a new century began.

Between 1772 and 1820 the milling center at Brandywine reached its zenith; in an area renowned for the most notable concentration of mill industries in America, Wilmington's Quaker millers had long been the dominant force in an industrial valley that was "making rapid strides toward perfection" (38). Their leadership had been continuous almost from the inception of their mills. But already a few miles upstream, the gunpowder mills of E. I. du Pont were grinding, under massive stones, the product which in the 19th century would replace superfine flour as the product synonymous with the name of the creek. At the end of the 18th century, Brandywine flour was a watchword in America. By the end of the 19th it would be gunpowder that focused the attention of a nation on the area.

The maritime-commercial activity of Wilmington waned after 1810 and the reputation of the flour mills on the Brandywine diminished correspondingly as the hub of the flour merchants' world shifted from Philadelphia to New York and the West. The westward movement of both the population and the wheat belt, improved methods of transportation, and a new technology presaged by the use of the steam engine were all causes of this displacement; and each step away from a dependence on the coastal and tidewater settlements was invariably followed by the rise of a new flour-milling center. This transition was a slow process, as was the decline of the local flour mills that accompanied it (39).

The westward movement was well begun by 1840 and the subsequent history of the Brandywine flour mills reflects the decline of the business which had been Delaware's first important industry as well as one of America's most celebrated collection of mills. In 1880 the mills on the south side of the creek stopped grinding; by 1926 the heirs of Canby, Shipley, and Tatnall sold the property on the opposite shore. After 184 years the Quaker milling oligarchy of Wilmington was no more. Its greatest monument is the flour-milling industry of modern America which can look directly to the Brandywine for its antecedents.

NOTES

1. Henri L. Bourdin, Ralph H. Gabriel, and Stanley T. Williams, eds., *St. Jean de Crèvecoeur, Sketches of eighteenth century America*, p. 145, New Haven, 1925. Carl Bridenbaugh, *The colonial craftsman*, pp. 59-60, New York, 1950. Charles B. Kuhlmann, *The development of the flour-milling industry in the United States*, passim, Boston, 1929.

2. See articles by author in *Delaware History*, vol. 7, March 1956, pp. 17-36, and September 1957, pp. 319-336.

3. Winslow C. Watson, ed., *Men and times of the revolution; or Memoirs of Elkanah Watson . . . from the year 1772-1842*, 2d ed., p. 227, New York, 1856.

4. *Travels in America 100 years ago*, pp. 69-70, New York, 1894.

5. J. Thomas Scharf, et al., *History of Delaware, 1609-1888*, vol. 2, p. 786, Philadelphia, 1888.

6. By 1816 "the trade, industry, and importance of the State of Delaware" were dependent upon the prosperity of the Brandywine Mills. See miscellaneous petitions, January 26, 1816, legislative papers, Delaware State Archives, Dover, Del.

7. From 1785 to 1800 the *Delaware Gazette*, Wilmington, is a treasury of advertisements reflecting milling activity in New Castle County and particularly along the Brandywine Creek. See in addition, Scharf, *History of Delaware*, vol. 2, pp. 880-897, 914-948.

8. *United States Gazette*, December 18, 1823.

9. "Extracts from the letter-books of Lieutenant Enos Reeves," *Pennsylvania Magazine of History and Biography*, vol. 21, p. 239, 1897.

10. See Kuhlmann (note 1), pp. 28-29, 38. Joseph Scott, *A geographical description of the States of Maryland and Delaware*, pp. 80-82, 90-91, 107-71, Philadelphia, 1807, provides an interesting comparison of the Brandywine and Ellicott Mills. Arthur G. Peterson, *Flour and grist milling in Virginia: a brief history*, *Virginia Magazine of History and Biography*, vol. 43, pp. 97-108, 1935, treats the James River mills.

11. See Bucks County Historical Society papers, vol. 5, pp. 527-528, 1926: Benjamin Ferris, *A history of the original settlements on the Delaware . . . and a history of Wilmington* pp. 302-303, Wilmington, 1846; *Pennsylvania Gazette*, Philadelphia, December 2, 1762; and Agreement and survey of lands, August 9, 1760, Tatnall Papers, MS., Historical Society of Delaware, Wilmington, Del.

12. *A journal . . . of the life, travels, and Christian experiences of . . . Thomas Chalkley*, p. 290, London, 1751.

13. Carl Bridenbaugh, ed., *Gentleman's progress: the itinerarium of Dr. Alexander Hamilton, 1744*, p. 15, Chapel Hill, 1948.

14. Some cursory remarks made by James Birket in his voyage to North America, 1750-1751, p. 54, New Haven, 1916. Birket visited Wilmington in December 1750.

15. Laurence Henry Gipson, Lewis Evans, p. 98, Philadelphia, 1939.

16. *Description of the streets and the main roads about Philadelphia*, 1754, *Pennsylvania Magazine*, vol. 18, p. 217, 1894.

17. *Travels through the middle settlements in North America in the years 1759 and 1760*, reprinted from 3d ed., 1798, p. 88, New York, 1904.

18. Philip Padelford, ed., *Colonial panorama, 1775*; Dr. Robert Honyman's journal for March and April, p. 11, San Marino, 1939.

19. The Deane papers, *Collections of the New York Historical Society . . . vol. 1*, p. 56, 1886. In Wilmington Deane was told that one vessel alone carried 30,000 barrels of flour a year to Philadelphia.

20. John A. Munroe, *Federalist Delaware, 1775-1815*, p. 28, New Brunswick, 1954; Henry Seidel Canby, *Family history*, Cambridge, 1945, and *The Brandywine*, New York, 1941; and William Guthrie, *A new system of modern geography; or A geographical, historical, and commercial grammar; and Present state of the several nations of the world*, vol. 2, p. 459, Philadelphia, 1795. Guthrie enumerates the mill industries in New Castle County near Wilmington. Besides a cotton mill of "considerable forwardness (on the Brandywine)" and a bolting cloth manufactory, there were "several fulling-mills, two snuff-mills, one slitting-mill, four paper-mills, and sixty mills for grinding grain, all of which are turned by water." In 1791, four years prior to Guthrie's enumeration, in addition to the flour mills, there were on the Brandywine, in the vicinity of Wilmington, six sawmills, a paper mill, a slitting mill, a barley mill, and a snuff mill, giving employment to over 100 persons and indirectly supporting scores of coopers, blacksmiths, weavers, cotton card makers, carpenters, and millwrights. By 1815 the flour mills were at their zenith, and an infant textile industry was assuming some importance; within 5 miles of the town, the Brandywine turned at least 36 water wheels and had "fall sufficient remaining for nearly an equal number." Near Wilmington, "Within a Semicircle of 20 Miles," there were said to be "14 Establishments with more than three Thousand Spindles, for manufacturing wool, & 27 Cotton Mills containing more than 25,000 Spindles," and in a petition to the Delaware legislature in January 1816, it was stated that: "The Utility and magnitude of the Mills and Works upon the Brandywine are not more celebrated than felt in every part of the United States. . . ." See *Return of manufactures, tradesmen, &c in Wilmington Delaware & its vicinity including Brandywine Mills . . . November 28th, 1791*, Alexander Hamilton papers, Library of Congress, and reproduced in H. Clay Reed, ed., *Readings in Delaware history, economic development* (mimeographed), p. 39, Newark, 1939; *Wilmington, Delaware, and its vicinity*, Niles' Weekly Register, vol. 9, p. 93, 1815-16. Minutes of the proceedings of the manufacturers of Wilmington, town hall 11 mo. 25th 1815, William Young papers, Historical Society of Delaware; and Memorial of the Brandywine millers opposing the altering of mill dams . . . January 26, 1816, legislative papers, Delaware State Archives, Dover, Del.

21. See Brandywine Millseat Company Survey, 1822. MS., Hagley Museum, Wilmington, Del. This survey shows the flour mills at their zenith. In addition, see *The Delaware Statesmen*, Wilmington, May 9, 1812.

22. J. Leander Bishop, *History of American manufacturers from 1608-1860*, vol. 1, p. 145, Philadelphia, 1861-68. By 1821, these mills ground 620,000 bushels annually and represented a combined capital investment of \$336,000. See Canby, et al., *Census schedules, Census of manufacturers of 1820*, New Castle County, Delaware, National Archives, Washington, D.C. The importance of the flour trade to Wilmington's millers and townspeople is reflected in many sources. for example: J. P. Brissot de Warville, *New travels in the United States of America performed in 1788*, pp. 188, 421-422, London, 1792; Broom, Hendrickson, and Summerl, *Letter book, 1792-1794*, MS., Historical Society of Delaware; *Delaware Gazette*, June 27, 1789, April 10, 1790, March 4, 1796, and June 26, 1799; *Ledgers and Journals of Thomas Lea and Joseph Tatnall*, Historical Society of Delaware; and Samuel Canby diary 1779-1796, MS., Yale University Library, New Haven, Conn.

23. *Mirror of the times and general advertiser*, Wilmington, May 21, 1806; Peter Bauduy to E. I. du Pont, August 20, 1802, Bessie G. du Pont, *Life of E. I. du Pont*, vol. 6, pp. 104-106; and for an estimate of the value of the water

right alone, see Caleb Kirk to E. I. du Pont, February 6, 1828, Hagley Museum MS. file.

24. Munroe, *Federalist Delaware*, pp. 152, 160-161, 173, 216 n., 217, 244, 246.

25. See Henry Seidel Canby, *Family History*; and J. T. Scharf, *History of Delaware*. For transactions of Brandywine Millers with Robert Morris, see Brandywine Mills Daybook, 1775-1783, MS., Historical Society of Delaware.

26. *Ibid.*

27. John C. Fitzpatrick, ed., *The writings of George Washington . . . 1745-1799*, vol. 9, pp. 151, 474; vol. 10, pp. 11, 219, Washington, 1931-1934. *Pennsylvania Magazine*, vol. 18, p. 482, 1894; vol. 19, pp. 73-74, 1895.

28. Louis Philippe, Comte de Ségur, *Memoirs and recollections of Count Ségur*, p. 323, London, 1825.

29. Watson, ed., *Memoirs of Elkanah Watson*, p. 277.

30. Louis B. Wright and Marion Tinling, eds., *Quebec to Carolina in 1785-1786: Being the travel and observations of Robert Hunter, Jr., a young merchant of London*, p. 176, San Marino, 1943.

31. Dr. James Tilton, *Queries*, *American Museum or Universal Magazine*, vol. 5, p. 381, 1789.

32. Francis Asbury, *Journal of Rev. Francis Asbury*, vol. 2, p. 136, New York, 1821.

33. Kenneth and Anna Roberts, eds. and trans., *Moreau de St. Méry's American journey, 1793-1798*, p. 88, New York, 1947.

34. Isaac Weld, Jr., *Travels through the States of North America and the provinces of upper and lower Canada during the years 1795, 1796, 1797*, vol. 1, p. 34, London, 1807.

35. Duke de la Rochefoucault Liancourt, *Travels through the United States of North America . . . 1795, 1796, and 1797*, vol. 3, pp. 493-501, London, 1800.

36. Robert Proud, *The history of Pennsylvania in North America . . . written principally between the years 1776 and 1780*, vol. 2, p. 255, Philadelphia, 1797-1798.

37. Christoph D. Ebeling, *Erdbeschreibung und Geschichte von Amerika*. 5 vols., Hamburg, 1797-1803. The section on Delaware was translated in 1883 and typed copies were presented to the Historical Society of Pennsylvania and the Historical Society of Delaware. Reference is to the copy in the Historical Society of Delaware (see pp. 93-94, 106).

38. A directory and register for the year 1814 . . . of the borough of Wilmington and Brandywine, Wilmington, 1814. And in the same vein, Niles' *Weekly Register*, vol. 6, p. 277, 1814, reported Wilmington "likely to become one of the most important manufacturing towns in the United States."

39. This trend is apparent in the 1830's when instead of drumming the advantages of manufactures, the editor of the local newspaper writes: "Our hopes have been fixed on the manufactories of the Brandywine, and of making Wilmington a manufacturing City, but this has been abortive. . . ." *Delaware Gazette*, October 8, 1833.



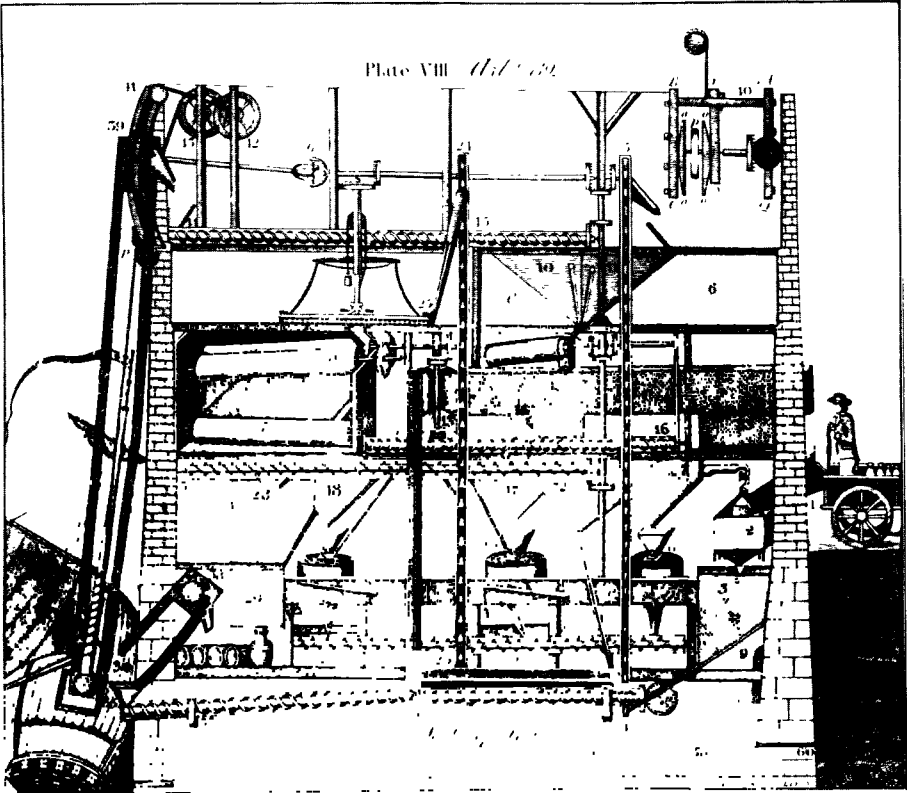
1. Joseph Tatnall (1740-1813), Quaker patriot, friend of George Washington and the first great industrialist of Delaware. His skill and energy made Wilmington the flour-milling center of early America. (Engraving in Scharf's *History of Delaware*.)



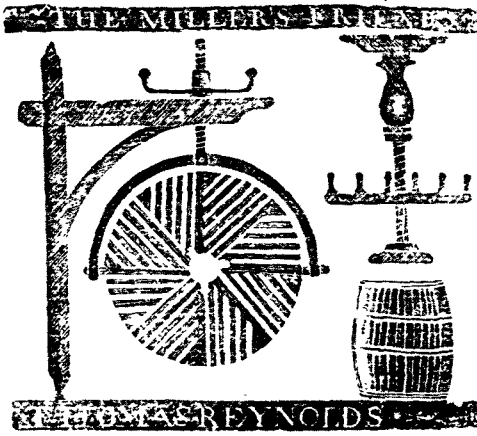
2. Oliver Evans (1755-1819) born at Newport, Del., a few miles west of Wilmington, was an ingenious, cantankerous man years ahead of his time. His inventions contributed materially to the renown of the Brandywine Mills and to the improvement of flour milling throughout the world. His work on the high-pressure steam engine made him one of America's first great engineers. (Henry Howe, *Memoirs of the Most Eminent American Mechanics*, 1840.)

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76	John Barry 2 to 100	6
77	John Barry 2 to 100	6
78	John Barry 2 to 100	6
79	John Barry 2 to 100	6
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96	John Barry 2 to 100	6
97	John Barry 2 to 100	6
98	John Barry 2 to 100	6
99	John Barry 2 to 100	6
100	John Barry 2 to 100	6

In 1776 a Quaker miller took time to record an event of some consequence, namely, an account of "the Roe Buck, & Liverpool Men of Warr & the 13 pensylvania Gunduloes" and their "Ingagement in the Delaware River Oposite Wilmington." (Brandywine Mills Daybook, 1775-1783, Historical Society of Delaware.)



Oliver Evans introduced the idea of automation, and his inventions— the elevator, conveyor, hopper-boy, descender, and drill—revolutionized the flour-milling industry. His machines, dubbed rattletraps, were clanking away in the Brandywine Mills as early as the 1780's, improving quality, increasing yield, and reducing the physical burden of milling. This plate of the "automatic mill" first appeared in 1795 in Evans's *Young Mill-Wright's and Miller's Guide*.



THOMAS REYNOLDS,
*Respectfully returns his thanks to the Public
 for their former favours, and informs them,
 that he carries on the*
Smiths' Business, at Brandywine
Mills,

In a more extensive manner than formerly.

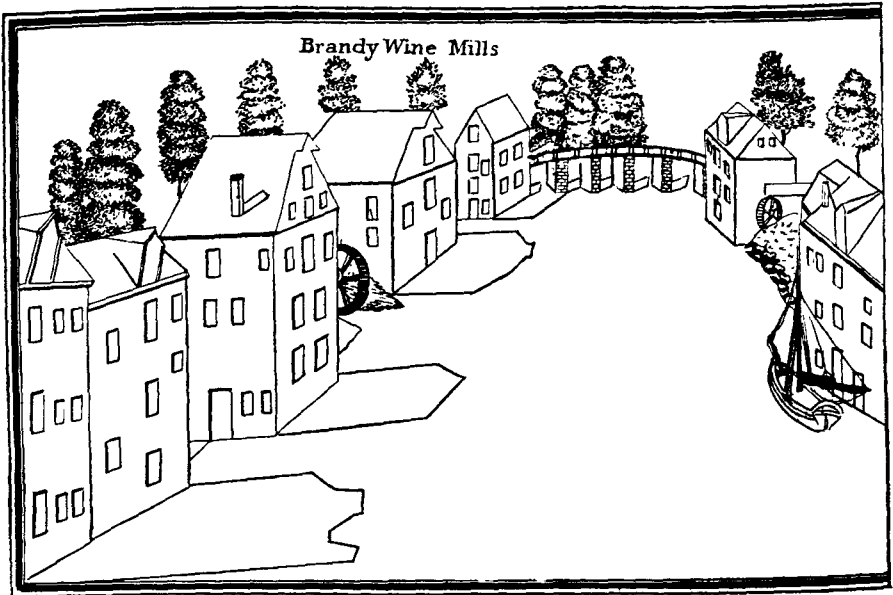
*He continues to make and repair Screws for
 raising millstones, packing flour and tobacco,
 for timber wheels, and Fulers and Printers
 presses.*

*Brands and Stamps in copper, iron and
 steel, cut in the neatest manner.*

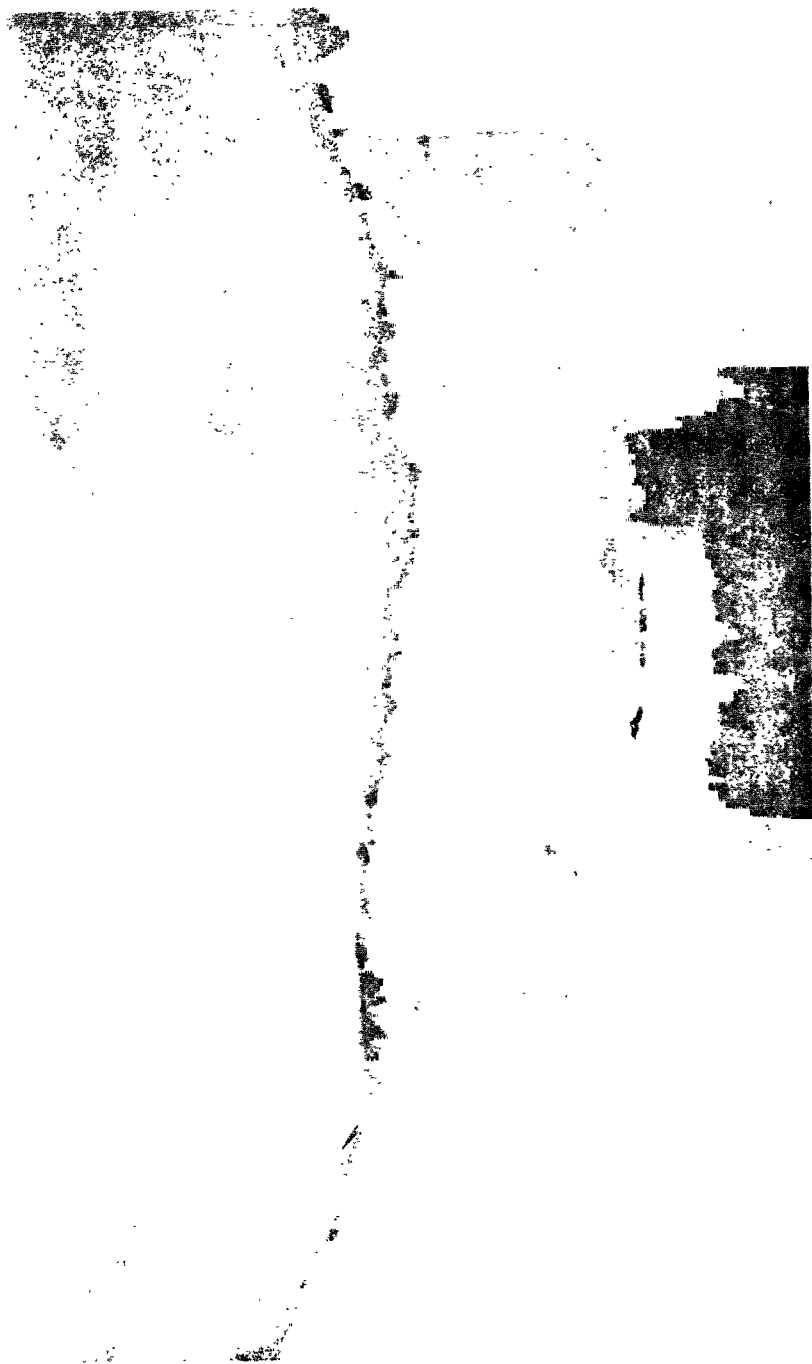
*Orders from any part of the continent will
 be thankfully received, and carefully attended
 to.*

March 18, 1790.

1. Despite mechanization, work was provided for scores of individuals including millers, millwrights, coopers, blacksmiths, and shallopmen. This blacksmith's advertisement appeared in the *Delaware Gazette*, March 20, 1790. (Historical Society of Delaware.)



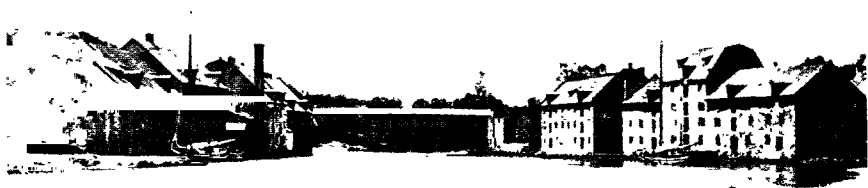
2. "Small craft, of apparently about ten or fifteen tons came directly alongside the mills" wrote Thomas Twining, but "sloops of a much larger size could mount the stream." This copper-plate engraving by an unknown engraver was done ca. 1804. It is one of several showing Wilmington's important "public" buildings. (Copper-plate; Historical Society of Delaware.)



Seemingly suggested by the earlier engraving, this painting is attributed to Albert Thatcher. Robert Sutcliff in 1804, the period depicted in Thatcher's painting, thought these mills "one amongst the many pleasant spots I have seen in this country." Oil, Hagley Museum, Wilmington, Del.



Wilmington was "famous all over America for its Merchant Mills." Handsome, extraordinary, charming, superior, or particularly pleasing were favorite adjectives of travelers as they crossed the Brandywine Bridge on the way to or from Philadelphia. In 1840 Bass Otis (1784-1861) provided ample evidence why "the remarkable grandeur of the Brandywine can be better viewed than described." (Painting owned by Lewis Rumford, II, Baltimore, Md.)



1. By the time the camera focused its harsh eye on the Brandywine Mills in the last decade of the 19th century, the once "charming prospect" seen by early travelers had begun to look tired and worn. (Picture Collection, Historical Society of Delaware.)



2. Today, not far from where Bass Otis painted in 1840, the scene has changed. Yet beside this quiet tidal pool were laid the foundations of the American flour-milling industry.

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